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THESIS

SUPPORTING THE FLEET: TAKING WORKFLOW TO THE WATERFRONT

by

Tobias A. Nassif

March, 1995

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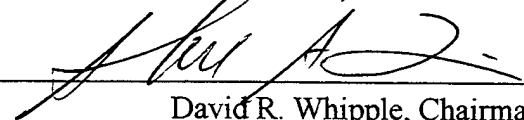
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ABSTRACT

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This Thesis analyzes the need of the PHD-NSWC to implement automated workflow technology and evaluates methods for incorporating the customer, namely the fleet unit, into the workflow process. The study employs an in-depth review of publications on workflow to determine what workflow is; an analysis of workflow requirements at PHD through the use of interviews; and a review of both commercial and military wireless networking technologies to interconnect ships at sea as a basis for recommendations.

This Thesis provides PHD-NSWC with three recommendations for connecting the fleet unit to PHD-NSWC. The first two using technologies available today, while the third proposal is a recommendation for the future based on technology still in development. It also provides recommendations as to where the inclusion of the fleet would be most effective for improving the workflow of the processes discussed.

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I. INTRODUCTION

A. THE PROBLEM

The duty of an In-service Support Engineering Activity (ISEA) to provide engineering support to the customer is an important part in maintaining fleet readiness. Traditionally, work processes at an ISEA are manually intensive, prone to errors, missing documents and normally result in long delays before solutions and answers to requests are delivered. As an example, a possible scenario at a typical ISEA is shown below.

"John, we just got word that the Engineering Change Proposal (ECP) on the Evolved Sea Sparrow Missile (ESSM) is in and we need to get it turned around quick. The proposal should be able to eliminate that safety issue with the fire enable switch."

"Ok Jane, I'll get started on it right away. When will the mailroom get it to me?"

"Should be any time now. Why don't you give them a call and see where it is?"

"Alright, I'm on it."

Two weeks later...

"John, how is the ESSM ECP working?"

"Well, I got it, gathered the references required to evaluate the proposal, wrote down my recommendations and forwarded them on to Technical Editors via the guardmail yesterday. They should have it now."

"Well I checked with them, they say they haven't received it yet. Hopefully they will get it today."

One week later...

"John, The Editors say they still did not get the comments you sent them, it must have gotten lost. Do you have another copy of your comments? If not could you get a copy of the proposal and re-submit your recommendations? Also, next time remember to make a copy of them in case this happens again."

Two weeks later...

"John, the editors got your stuff, but they are waiting for the engineers to get there comments in. Apparently they had to go down to San Diego and check out some of the recommendations onboard a ship to see if they will work properly. They should get back soon and this thing can get finished."

Two weeks later...

"Jane, how is the ESSM ECP? I haven't heard of a date for the CCB (Change Control Board) yet."

"Well, the editors just received the engineers input, and they should be scheduling the meeting for sometime next week..."

As the scenario above showed, the current process is not the most efficient of designs. Although the scenario did not address the actual flow of the work in the process, it shows the typical result of poorly designed work processes.

The automation of a workflow process could do a lot in reducing the problems seen above and speed up the document processing procedures.

B. BACKGROUND

This study analyzes the need of the Port Hueneme Division-Naval Surface Warfare Center (PHD-NSWC), an ISEA, to implement automated workflow technology and evaluates methods for incorporating the customer, namely the fleet unit, into the workflow process.

PHD-NSWC is in the process of implementing a centralized technical data management system known as the Integrated Data Management System (IDMS). Concurrently, the Department of Defense (DoD) is in the process of implementing the Joint Continuous Acquisition and Lifecycle Support System (JCALS) in support of DoD's Continuous Acquisition and Lifecycle Support (CALS) initiative (see Appendix A for a description of the CALS Initiative). These systems were initiated as a means to track and review contractor data requirements lists and to manage the work involved in developing and supporting DoD weapon systems and, in the case of IDMS, US Navy Fleet Weapons Systems. The JCALS system contains a custom workflow manager designed by the

contractor Computer Sciences Corporation (CSC), whereas the IDMS contractor has yet to select a workflow manager to incorporate into the system. This thesis is part of a project commissioned by PHD-NSWC to study workflow automation and its use at the ISEA site. The project, which is broken down into various areas covered by other thesis work, includes the determination of a workflow manager for IDMS, cases studies of commercial corporations implementing workflow in their business improvement strategy, and further work determining the implementation of workflow at PHD based on the workflow manager chosen and PHD's workflow requirements. This thesis will investigate PHD's need to provide a means of remote connectivity between PHD and the fleet in order to bring customer input to the work being conducted at PHD as well as allow customer access to the information servers which will be maintained at PHD.

C. OBJECTIVES

This study will provide PHD-NSWC with recommendations on how to link electronically PHD-NSWC, and its customers, the fleet units, for information exchange and document review. This electronic link shall enable PHD-NSWC to review data requirements with customers and or contractors at remote locations as a request for work is developed.

In support of this tasking, the following research questions will be answered:

- What is workflow?
- What are the workflow requirements of the Port Hueneme Division-Naval Surface Warfare Center (PHD-NSWC)?
- What network considerations are required to accomplish the integration of fleet units into the workflow environment?

This thesis is broken down into three core areas corresponding to the research questions. The first portion of this study reviews the concept of workflow and the tools for workflow implementation. The second part captures the current work process at PHD-NSWC and determines PHD's requirements for an automated workflow implementation. Finally, it will review the current and planned methods of incorporating the fleet units into PHD-NSWC's established workflow.

D. RESEARCH METHODOLOGY AND ORGANIZATION

An in-depth review of publications, reports, and articles on the subject of workflow has been conducted to understand the concept of workflow and to prepare for the analysis of workflow requirements at PHD. Also a review of both commercial and military wireless networking technologies to interconnect ships at sea has been conducted and used as a basis for recommendations.

The analysis of PHD-NSWC's current work processes was conducted through interviews with the process controllers at PHD and a review of their current workflow documents.

This thesis is organized into five chapters. The remainder of this thesis is organized as follows:

- Chapter II, "Workflow: An Overview" provides an in-depth overview of workflow, what it is, how to implement it, and the tools needed for implementation.
- Chapter III, "Workflows at PHD-NSWC" provides an overview of PHD-NSWC and captures the current workprocess of an ECP, ORDALT and technical manual change in the Aegis weapon system.
- Chapter IV, "Connectivity Options to the Fleet" investigates the various technologies that are available today as well as those in development to interconnect ships at sea with PHD-NSWC.
- Chapter V, "Recommendations and Conclusion" will provide the recommendations for workflow implementation and network connectivity as well as provide a review and executive summary of the project.

II. WORKFLOW: AN OVERVIEW

Before attempting to determine what the workflow requirements of PHD-NSWC are, it is necessary to determine what it means when we say "workflow". We first need to determine what workflow is, where it came from, how it is used, and where it will be heading.

A. WHAT IS WORKFLOW?

The concept of workflow automation has been around for less than five years. With its origins coming out of the work improvement field, workflow has become one of the principal enabling tools for business process reengineering. Workflow and its associated software tools "allow new structures and new flexibility not available when these rules were first created, and tends to strongly encourage business process reengineering." (Silver, 1994, p.137)

1. Business Process Reengineering

The idea of workflow automation began as a result of organizations' desire to improve the way they conduct business. Throughout the seventies European and Asian, particularly Japanese, businesses eroded the American industrial base by providing quality products at reasonable prices. As a result, American manufacturers scrambled throughout the eighties to improve quality in their products and manufacturing processes. Throughout those years many different management theories were employed, the latest of which is a result of the influence and availability of computers and associated networking equipment.

What exactly is business process reengineering (BPR)? As with workflow it has different meanings to different people. Simply put, BPR is the "fundamental rethinking and radical redesign of business processes to achieve dramatic improvement in critical contemporary measures of performance such as cost, quality, services and speed" (Hammer and Champy 1993, p.32). It "involves analyzing how an organization does its work now, and how it could be changed to make the process more efficient, particularly

with the application of technology." (Silver, 1994, p.137) BPR aims at replacing old and outdated work methods with new or streamlined methods that focus on core business principles: end user empowerment, customer service, product quality, and fast product design. It seeks to overcome fragmentation caused by the division of labor into many narrowly specialized roles requiring so much coordination. The focus shifts from task management to process management (Soles, 1994, p.72). Other definitions of BPR exist, but in essence they are the same.

For any BPR endeavor to succeed, two key factors must be present. First and foremost, the call for reengineering must come from and be supported by the top level of management. Due to the many functional boundaries to be crossed by the reengineering process and the impact it could have on individual "fiefdoms", without upper level management support, any attempt at reengineering the process is doomed to fail. The second key to successfully conducting a reengineering project is to have inputs from the end users. In order for the project to be successful, the user must be involved. Reengineering a business without understanding the real user and without a pragmatic and incremental approach to introducing new technology would be a flawed process. Only the day-to-day user of a process truly understands what happens and how to improve on the work he/she conducts. Finally, any reengineering effort should be developed unobstructed by current practices. The goal is to find the most efficient and productive method for carrying out a task without regard to the way it was done in the past.

2. Workflow Definition

As we saw above with BPR, "workflow" can mean different things to different people. In general, a workflow is the sequence of actions or steps, in sequential and/or parallel arrangement that comprise a business process. An automated workflow is the workflow that is integrated with enabling information technology. Since today's business processes invariably involve the use of information technology, the term workflow

implies "automated" workflow and many critical issues in workflow are concerned with how to integrate information technology into the workflow.

Whether labeled process coordination, workflow, or work management, the concept of designing systems and applications that mirror human and task interaction has its roots in the office environment. (Howard, 1994, p.187) Thus workflow applies many of the principles of factory automation and industrial engineering to the process of work management in an office environment. (Koulopoulos, 1994, p.7) As the manufacturing industry automated and labored to improve its work processes, the need for improvement in the administrative portion of businesses and those businesses not involved in manufacturing was recognized. The economic pressures to increase the productivity of office work, in combination with the nearly universal networking of powerful multi-windowing desktops, make the future growth of workflow automation software a sure thing. (Silver, 1994, p.154)

The early use of workflow in the office environment was centered on document processing. For years organizations had used automated systems for a variety of document processing tasks. However these systems were for the most part standalone "stovepipe" systems (i.e., word processors, desk-top publishing systems). As one system produced a document it was carried or delivered from person to person who were then required to comment on that document. Workflow attempted to link those independent tasks allowing the workers to complete tasks faster and more accurately.

As workflow manifests its benefits, it has gained a new meaning as a major component of methodologies such as BPR and process improvement. According to leading workflow advocate Thomas Koulopoulos, "Workflow [is] a tool set for the proactive analysis, compression, and automation of information based tasks and activities." (Koulopoulos, 1994, p.7) As such we see that workflow solutions are not a single technology or product, but are actually made up of a number of technologies, methodologies and tools such as database storage, local and wide area communications, graphical desktops, store-and-forward messaging, and process definition techniques.

(Burns, 1994) The idea behind workflow technology is to create a single environment to manage the complexity of multiple office automation environments. (Koulopoulos, 1994, p.30)

a. Conceptual Requirements of Workflow

Just as there are variations to the definition of workflow, there are differences in opinion as to the components that make up workflow. As a baseline, we can say that all workflows must include these three conceptual requirements: action, coordination, and people. (Burns, 1994)

(1) Action. Workflow automation systems and processes need to be active in the performance of their tasks. They should make decisions based on the conditions of flow set during design, notify personnel involved in the process of work required to be performed, and report the status of a particular instance of a workflow and any delays or problem experienced in the system.

(2) Coordination. Workflow automation systems should facilitate the coordination of the work process, relieving people from coordination overhead. This allows work managers to concentrate on other tasks and be available to perform other duties.

(3) People. Finally, workflow systems must be people oriented. They must focus on the people doing the work, not just information processing. They must incorporate the concepts of work from the perspective of how people work, not just the tasks they perform. It must be remembered that as with any system, if it does not relate well to a user, it will not be used.

b. Workflow Architecture

Workflow applications use five distinct layers of structure to categorize the organization of information management activities: processes, instances, folders, rules (which consist of rules and routing), and documents. (See Figure 2-1)

(1) The Process Model. The process model consists of a series of tasks and rules that must be defined for each process that takes place. Specific tasks have

The Workflow Architecture

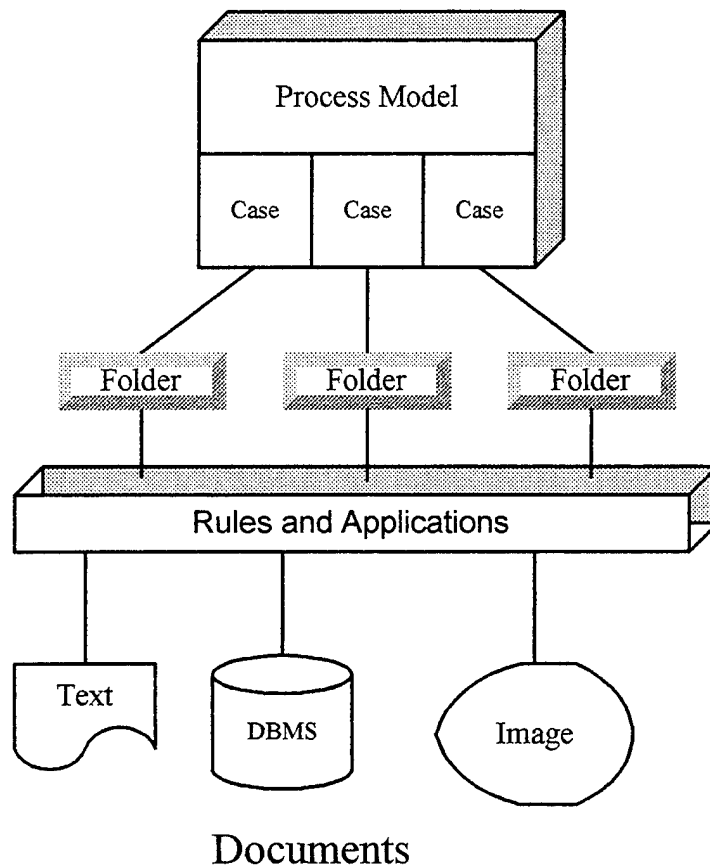


Figure 2-1. The Workflow Architecture - The architecture of a workflow system includes five layers of information in addition to the roles and routing information.

rules associated with them. Each task and its associated rules must be defined to the workflow system.

(2) Instances. An instance is an individual occurrence of the process model. Each time the workflow process is invoked a new instance is created. Instances are also referred to as cases by some people.

(3) Folders. Folders contain a logical group of documents. The folder may contain any combination of data types including text, image, and data from multiple sources.

(4) Rules. Rules define the specific processing activities that are involved in routing workflow documents and working within specific applications. Rules are defined by roles and routing. A role is the part that a participant plays in the specific workflow. Each participant has established roles that must be defined as part of the workflow definition. Each participant is described in terms of location, job function, supervisor, and security level. An employee may be an individual participant as well as part of a workgroup. Workgroups can consist of a group of individuals working on a project, a department, or a group of individuals that share the same job function. One individual may belong to multiple workgroups at one time, depending upon the type of application. Role definition distributes tasks to the appropriate individuals for completion. It also allows for workload balancing and distribution to the appropriate employee based on skill level.

(5) Documents. The data itself. This is represented by a single document or a group of documents, which are enclosed within a folder, which in turn is controlled by an instance. It should be noted that a document is almost always associated with an application that must be initiated in order to view and work with the data. In a workflow application the document is the unifying force for all data and the applications used to process that data. The document represents not only the actual data but also the formatting, processing and presentation of the data. The ability to invoke and integrate the presentation of these documents is a key aspect of workflow.

Workflow routing controls how documents move from point to point in the workflow. There are three types of routing: sequential, parallel, and dynamic or conditional routing (See Figure 2-2).

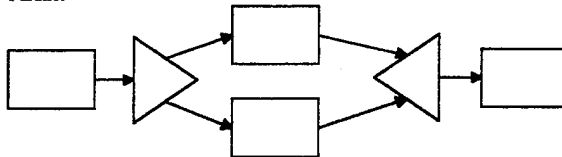
- Sequential routing follows a linear path from one task to another. It is clearly defined with little variation. One task must be completed before the work is routed to the next point.

Workflow Routing

Sequential



Parallel



Conditional

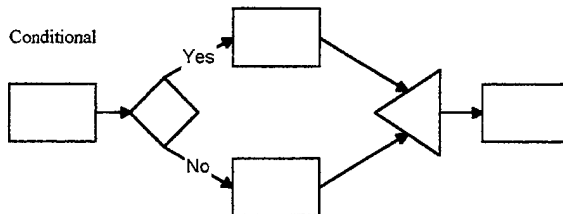


Figure 2-2. Workflow Routing - Workflow routing controls the movement of documents in the workflow. Routing can be sequential, parallel or conditional.

- Parallel routing enables multiple tasks to occur at the same time. Eventually all the routes are brought together at a rendezvous point. They are held there until all the tasks have been completed before initiating the next task.
- Conditional routing is determined by the conditions which occur dynamically in the process. The system must be able to determine the appropriate route based upon the information that is received along the way.

It should be pointed out that concurrent and parallel routings are not necessarily synonymous. In a parallel workflow routes may be completed at different times, concurrent workflows are completed at the same time. Although both rendezvous

at the same point, the parallel process may include idle capacity along one of its routes. (Koulopoulos, 1994, p.136)

c. Categories of Workflow Applications

Another area of debate in the workflow world is the categories or types of workflows. Regardless of the names given, there are two categories of workflow that should be supported by any workflow system. They are the ad hoc or unstructured, and the transaction-based or structured.

(1) Ad Hoc/Unstructured. Unstructured workflows are usually for project oriented applications such as document development which is difficult to automate in a standard way. They typically change frequently and the participants or the roles they play in the workflow may also change frequently. Consequently users need a lot of control over the process as it occurs and over the design of the process itself. Unstructured workflow automation provides significant improvement to individual productivity but generally not to the organization or the process as a whole. Unstructured workflows typically have less sophisticated routing needs while structured workflows will require a great deal of robustness and computer control.

(2) Transaction-based/Structured. Structured flows are typically simple, well defined processes such as administrative tasks like expense reports, time sheets and check requests. In these applications processes and participants don't change frequently. Solutions often require parallel workflow coordination, conditional routing, and desktop management with alerts, reminders and management aids. The rules that define a structured workflow can be precisely delineated and executed under a transaction-based model. Transaction-based workflow is generally a high volume, production based environment that is characterized by repeated tasks and little variation among cases. Throughput is the primary concern in this environment.

Structured workflows are typically mission critical and frequently extend to external organizations. Examples include purchase order processing, litigation support and loan processing.

d. Workflow Makeup

A workflow task is made up of the following events: initiation, notification, iteration or negotiation, duration, dependence, and completion (See figure 2-3). An initiation is an event that triggers a workflow process. Notification is an electronic message that is initiated through the occurrence of any other workflow event. An iteration or negotiation is the repetitive execution of an object, using substantially the same rules each time. This is the meat of the workflow process. Duration is the time required to complete the event or the period of time for the deferment of a specific event

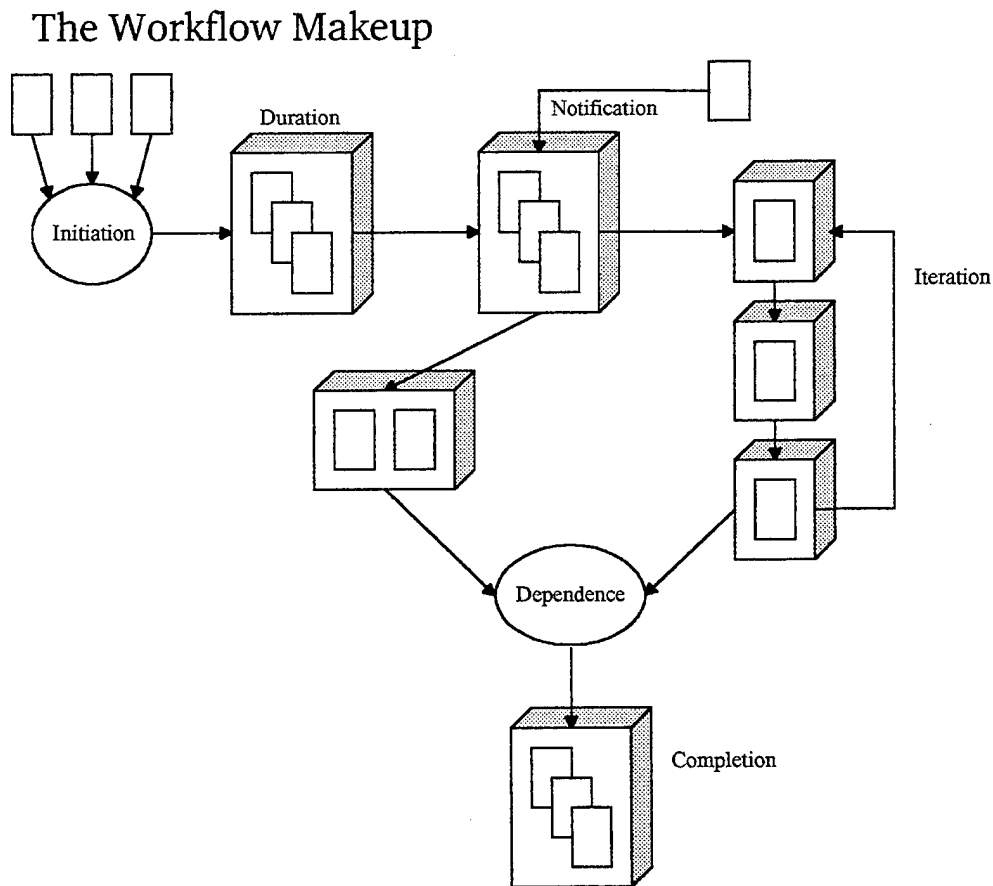


Figure 2-3. The Workflow Makeup - The six attributes of a workflow task: initiation, duration, notification, iteration, dependence,

until its dependencies have been satisfied. Dependence represents prerequisite conditions or objects that must be satisfied or initiated on prior to the execution of the dependent object. Finally, completion is the last event in a workflow process for a particular object and it is the signal to the system that the particular workflow instance has been completed. (Koulopoulos, 1994, p.150)

3. Workflow and Business Process Reengineering

What are the differences and similarities between workflow and BPR? Unlike Hammer and Champy's reengineering, workflow does not require radical change and exceptional sponsorship in the organization.

Workflow can...establish the foundation for a sound reengineering effort. But to do this, workflow must be used as more than an automation tool. It must also provide the analytical and reporting tools that help change managers better understand their organization's business processes. In this light, workflow becomes an overall discipline for restructuring information systems and not another competing technology. (Koulopoulos, 1994, p.40)

As many reengineering implementors have seen, workflow automation is a critical enabler of the reengineering effort:

- The real gains from reengineering require attention to workflow. (Soles, 1994, p.81)
- Reengineering is facilitated by the use of an incremental or pilot implementation of workflow technology. (Koulopoulos, 1994, p.39)
- Although workflow appears to represent one component of total reengineering, no reengineering project should proceed without the use of workflow, at the very least as an analytical tool. (Koulopoulos, 1994, p.41)

Workflow facilitates TQM and other process improvement methodologies by providing tools that bridge potential gaps between layers of management. (Koulopoulos, 1994, p.16) As a part of BPR and other process improvement methodologies, it is agreed that one must include the use of workflow. On the other hand, the use of workflow does not require that the organization go through a reengineering or process improvement phase. It is possible the existing process can be automated the way it is currently structured. (Soles, 1994, p.81)

In addition, although workflow can be implemented with just a technical perspective and no deep understanding of the process itself, BPR requires more than just a technical implementation. To be effective, BPR (and its workflow implementation) must also be an educational process for the personnel involved. The user must understand the reason for the change and realize why it is being conducted.

B. WORKFLOW TOOLS

1. What are Workflow Tools?

Workflow tools have evolved out of, and contain key elements of, several established technologies including e-mail, project management, database management, object oriented programming (OOP), and computer aided software engineering (CASE). (See Figure 2-4) All these technologies attempt to solve the problem of fragmented and isolated information. (Koulopoulos, 1994, p.121) The purpose of workflow tools is to

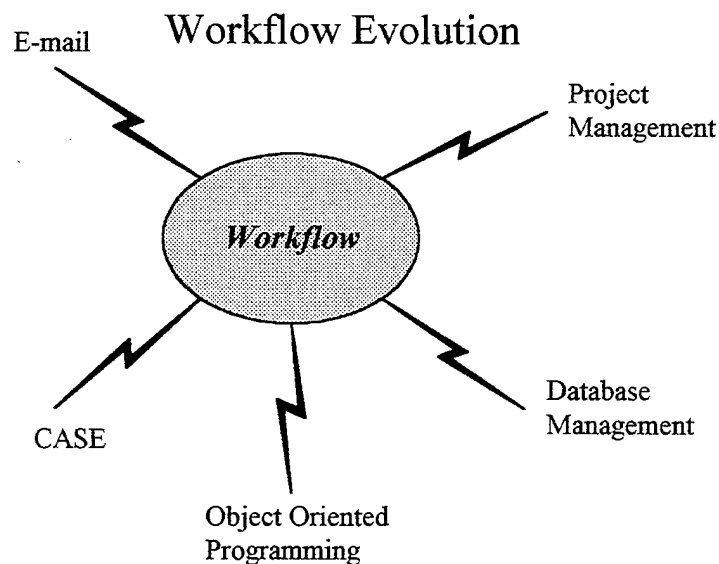


Figure 2-4. Workflow Tools - Workflow tools are combination of a number of other technologies each contributing their own uniqueness.

take business problems and translate them into technical solutions that streamline work processes and make them more efficient. Designed for a network environment, workflow software boosts the number of work processes that can be completed by a workstation and its user(s). (Howard, 1994, p177) These tools are provided to enable the workflow technology to interface with the user, platforms, and the data structures at each layer of the workflow architecture. (Koulopoulos, 1994, p.139)

2. Components of Workflow Tools

Workflow tools are made up of four basic components. It is these components and their interactions that define the characteristics of a workflow toolset. Of the four components, the most important and least understood is the workflow management engine. The other components are the deployment environment, workflow builder, and administrative utilities.

a. Workflow Deployment Environment

The workflow deployment environment is the interface with the user. It is responsible for the coordination and management of the flow of work. In many workflow systems, the work is completed in a personal productivity and/or legacy application and then managed by the workflow system. Some systems don't use a single deployment environment, but rather track the work as it flows among desktop applications. In essence, these workflow applications basically workflow enable your word processor, spreadsheet, e-mail, etc.

b. Workflow Builder

The workflow builder is the method of defining the workflow applications. Its implementation can vary from complex scripting languages to graphical user interfaces with point and click flowcharting type tools. A workflow builder provides specific tools and interfaces for defining the flow of tasks in the process to be automated, for defining the roles of the people doing those tasks, and for defining the rules by which the flow is determined. In short, it is used to define rules (routes and roles of the

business process) to identify data information or objects that are being worked on, and to bind all these to the deployment environment. The workflow builder is visible to the developer but may not be to the user. Many of the ad hoc tools allow the user to modify the workflow after the application has been built. The builder is the most significant differentiator between workflow products. The demand for tools that are capable of constructing, maintaining, and modifying complex and constantly changing workflows make this a challenging area.

c. Workflow Management Engine

The workflow management engine is the underlying engine that manages the actual running of each instance of the business process. Every workflow application has one, although it is the least visible and least understood part of the workflow system to the average user. The engine is responsible for tracking the progress of each instance and providing the system administrator with information concerning the progress of each instance of work. The workflow engine may include the internal database that tracks the status of each work package, maintains the queue tables and keeps track of the forms or workflow variables. The workflow engine is middleware; as such, users and developers must understand what services it provides for it is a vital part of not only the workflow system, but also of the organization's distributed computing environment.

d. Administrative Utilities

The administrative utilities include the functions of assigning users to processing functions, defining security and privilege levels, viewing the status of various queues, and generating management reports. In some systems and writings, the administrative system is included within the deployment environment. However, the importance of security in ever growing distributed systems warrants that the administrative functions carry its own identity. (Silver, 1994, p.151) (Marshak, 1994, p.175)

3. Selection of Workflow Tools

When selecting a workflow solution, there are a number of factors that should influence the selection of the tool. (Burns, 1994) One key factor is the ability of the tool to integrate with other applications, external data sources, paper based systems and platforms that are used by the organization. Changing the entire software suite of an organization to integrate workflow may cause more productive harm than good.

A second key factor is the sophistication of the routing capability as determined by the degree of parallelism, conditionals, exception handling, and the degree of computer control verses user control. Is there a need for a number of instances and multiple processes to run simultaneously and be reconciled at some point or is sequential routing sufficient? How sophisticated do the conditions need to be, how much workflow can be accomplished without user intervention such as extracting data from external sources, spawning processes, and making decisions based on conditionals? These types of questions should be addressed to see what the organization's requirements are as well as the ability of the tool to support them.

Robustness, a catch-all category that includes administration, security, and audit trail is another key characteristic of a workflow product. The need to simulate the workflow as it is developed, its scalability, and error recovery are additional factors in the category. The more complex the application the tool will be used for, the greater the requirements for simulation software to be able to anticipate problems and bottlenecks during design.

How frequently the application changes in terms of the process itself, the user's requirements, the number of participants, and their roles is also important to consider. Ad hoc workflows have a high degree of change while enterprise-wide, transaction-based workflows are characterized by infrequent change. A tool may be suited for one or the other or may be able to handle both types of workflow well. Regardless of the type being used, it is important that the tool be able to handle the job it is intended to perform.

C. PROBLEMS AND CONCERNS WITH WORKFLOW

Though it may seem obvious that workflow and its associated tools are the savior of the modern business world, there are, as with any new technology/technique, a number of problems and concerns regarding it. These problems are not just associated with putting the technology on the desktop, but also in the mindset of the individuals managing and using the technologies.

1. Automation Myths and Realities

As many IS managers know, there are no easy answers to complex questions. One of the greatest myths in the business world is that management always knows best when in reality the truth is that management does not always understand life in the trenches. It is important to understand that what may seem like a great idea to management may not be able to be implemented in the organization in the way they want. This leads into the second myth that many top level personnel hold, that virtually all work processes should be translated into electronic processes. Whereas this may seem like a good idea to those that relish in the technology, some processes should not be codified given their innate complexity. Workflow systems in particular can only handle certain types of processes as we have seen. Highly intricate and complex processes may not be able to be adapted to the current generation of tools available.

A third myth that is often "deflated" upon implementation is that all computer systems simplify jobs and reduce costs. As any manager who has installed an automated system can attest to, information systems are often hard to install, implement, and costly to maintain and support. This is especially true for the organization that has no previous IT background or experience, and expects savings and increased productivity from the start of a project.

The final myth that needs to be addressed is the myth that electronic information is always better than paper. There are still instances in which paper based information is still superior to electronic. In fact it has been shown that people must see an immediate

two-to-one improvement in information processing capabilities to justify the disruptive transition cost away from paper (Howard, 1994, p.187).

2. Workflow Tool Concerns

Besides the myths that normally accompany the introduction of a new technology, the current status of the workflow tools has also caused some concern with current and potential workflow users. The number one concern is the lack of security inherent in the current crop of workflow tools. Workflow tools need to support more layers of security or integrate with existing security systems before they are ready for wide scale enterprisewide deployment. A tough issue to face, security is not only a concern with workflow but with the entire distributed computing concept.

A second concern with workflow tools is the inability to integrate tightly enough with other applications and platforms. Workflow Applications should "lie like a blanket across an entire network and have [the ability] to be integrated with most other applications." (Fogarty, 1994) In addition to being able to integrate with other applications, connecting to various platforms presents another concern; one cannot find a Workflow tool that will work across Macintosh, UNIX and DOS/Windows based systems. In fact, only two vendors support Macintosh platforms at all.

A third and more serious problem with the current generation of workflow tools is that they don't include tools to build and modify complex workflow models for large organizations. The scripting tools included in most workflow packages lack the sophistication needed to let users build their own data modeling or analysis applications. Another concern displayed in workflow is the difficulty of building and identifying models of work processes and the ability to take those models and apply the workflow theory to them. As a result, the concern over the current offering of workflow products is holding up wide acceptance of workflow in many organizations. (Fogarty, 1994)

III. WORKFLOWS AT PHD-NSWC

In the preceding chapter the definition of workflow was established and the requirements for a good workflow solution were described. This chapter will capture actual workflow processes in a DoD organization, namely the Port Hueneme Division of the Naval Surface Warfare Center (PHD-NSWC). First an overview of the PHD-NSWC will be presented to give the reader an understanding of the organization's mission. Following will be an analysis of the ECP, ORDALT, and technical manual change workflow process as they currently exist in the organization.

A. PHD-NSWC OVERVIEW

1. Charter of PHD-NSWC

The Port Hueneme Division of the Naval Surface Warfare Center is an in-service engineering center. As such it has the responsibility for coordinating all elements of in-service support for surface fleet combat, weapon and underway replenishment systems and ensuring those elements are able to work together. The engineers, technicians, logisticians and support personnel work together on the ship system life cycle including: system conception, design, development, production, installation, testing, fleet introduction, initial follow-on, and in-service operation.

The command directs much of its effort toward the engineering development, test and evaluation, and production phases of surface fleet weapons systems. Systems such as NATO Seasparrow, Harpoon, Tomahawk and Aegis are programs which PHD-NSWC has been involved with from conception to fleet installation. (NVCN, 1994)

2. History

The need for an activity such as PHD-NSWC became apparent following World War II. With the development and installation of complex surface missile systems onboard Naval vessels, Navy officials saw that centralized control and direct supervision were essential for monitoring these systems' progress.

In 1963 the Naval Ship Missile Systems Engineering Station was established at Port Hueneme with six military, 38 civil service and 14 contractor personnel to support 45 ships with a total of 124 systems. As time progressed, the command broadened its role as in-service engineering agent for missile systems and became involved in the entire combat system. With the increase in responsibilities, the name of the organization changed to Naval Ship Weapon System Engineering Station (NSWSES).

NSWSES became the Port Hueneme Division, Naval Surface Warfare Center (PHD-NSWC) as part of the Department of the Navy's plan to consolidate Navy research, development, test and evaluation, engineering and fleet support activities. The Port Hueneme Division is the Navy's combat and weapons systems in-service engineering division of NSWC.

B. ANALYSIS OF CURRENT WORKFLOWS

To determine how workflow should best be structured and which workflow manager would be most appropriate for an organization, a study of the current workflow practices of the organization is essential. The variety of tasks and organizations at PHD-NSWC make it difficult to come up with a comprehensive description of current workflows. For the purpose of this thesis and follow-on studies, we rather focus on a few important workflows at PHD-NSWC. The workflows to be examined are an Engineering Change Proposal (ECP), an ordnance alteration (ORDALT), and a technical manual change for systems related to the AEGIS Weapons System. The ECP, ORDALT and tech manual change were chosen since they are basic workflow processes that are undertaken by all divisions of PHD-NSWC. Following the description of the workflows as they are accomplished, the need for the inclusion of the fleet units into these workflows will be discussed.

1. ECP

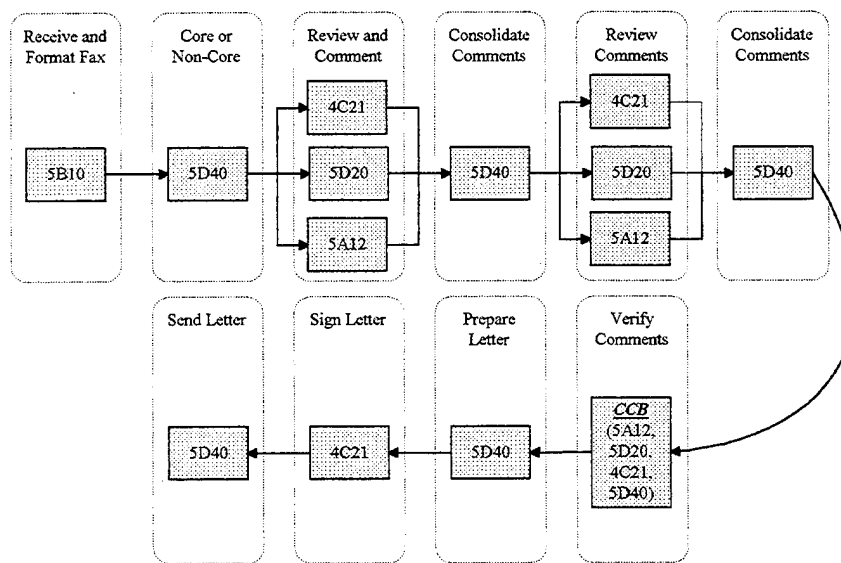
An Engineering Change Proposal (ECP) is a request by the system's contractor for a change to the system in question (See Figure 3-1). The ECP work process for the Aegis

weapon system has been partly automated through the use of IDMS. ECPs are received by PHD-NSWC Code 5B10 via fax from NAVSEA PMS-400 (Aegis Program Office).

Upon receipt, the fax document is converted into an Interleaf document by Code 5B10 and then electronically routed to Code 5D40 via the IDMS system. Code 5D40 determines if the ECP involves "core" Aegis systems or "non-core" equipment that is associated with the Aegis weapon system but not a direct part of it (i.e., Harpoon or

ECP Workflow for Aegis Weapons System

Core Aegis Equipment



Non-Core Aegis Equipment

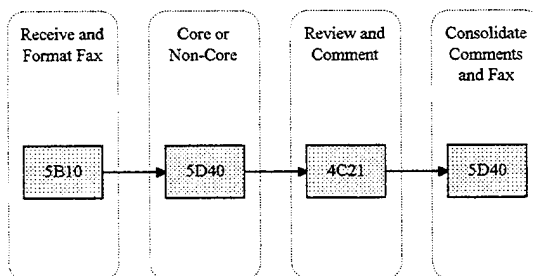


Figure 3-1. ECP Workflow - The ECP process is broken down into core Aegis and non-core Aegis equipment.

Tomahawk). Core Aegis systems are those that are native to the Aegis system such as the SPY-1 radar, the Aegis Display System (ADS), Command Decision System (CDS), and the Weapon Control System (WCS).

For non-core systems, the ECP is passed to the Code 4C21 engineers who determine if the proposal will interfere with any of the core Aegis systems. For those ECPs that are core Aegis, the ECP is passed to 4C21, the maintenance and supply personnel at Code 5D20 and to the logistics support personnel at Code 5A12. The divisions of 5A12 make their comments as to the effect the ECP will have on the system as does the 4C21 engineer. These comments are then compiled by Code 5D40. Once compiled, the ECP with the comments are rerouted back to the personnel that made the comments so that all involved can see the comments made by the other divisions. After the comments have been reviewed by the other parties and any further comments are made, the package is recompiled again by 5D40. After consolidation of the comments, the package then goes to the Configuration Control Board (CCB). At the CCB, the personnel involved with the ECP review and comment process come together and verify that comments made and the ECP are valid. Once the CCB is concluded and the ECP has been validated, a letter is prepared by Code 5D40 addressed to PMS 400F and 400B and signed by the Code 4C21 engineer who verifies the accuracy of the ECP. After the letter is signed, it is sent by 5D40 to PMS 400F and B. This is the end of the ECP process for an Aegis system. (Suwyn, 1994)

2. ORDALT

An ORDALT is the result of an approved ECP. Once approved by PMS 400, the ECP is designated as an ORDALT and the order to procure the ORDALT instruction is released. The majority of an ORDALT instruction is developed at PHD-NSWC. Receiving inputs on the technical information and drawings from the System Design Agent (SDA), the ORDALT's contractor, Code 5D40 has the responsibility for completing the remaining portions of the draft instruction (See Figure 3-2). The preliminary draft instruction is passed to Codes 5A12, 5D20, and 4C21. These codes are

ORDALT Workflow for Aegis Weapons System

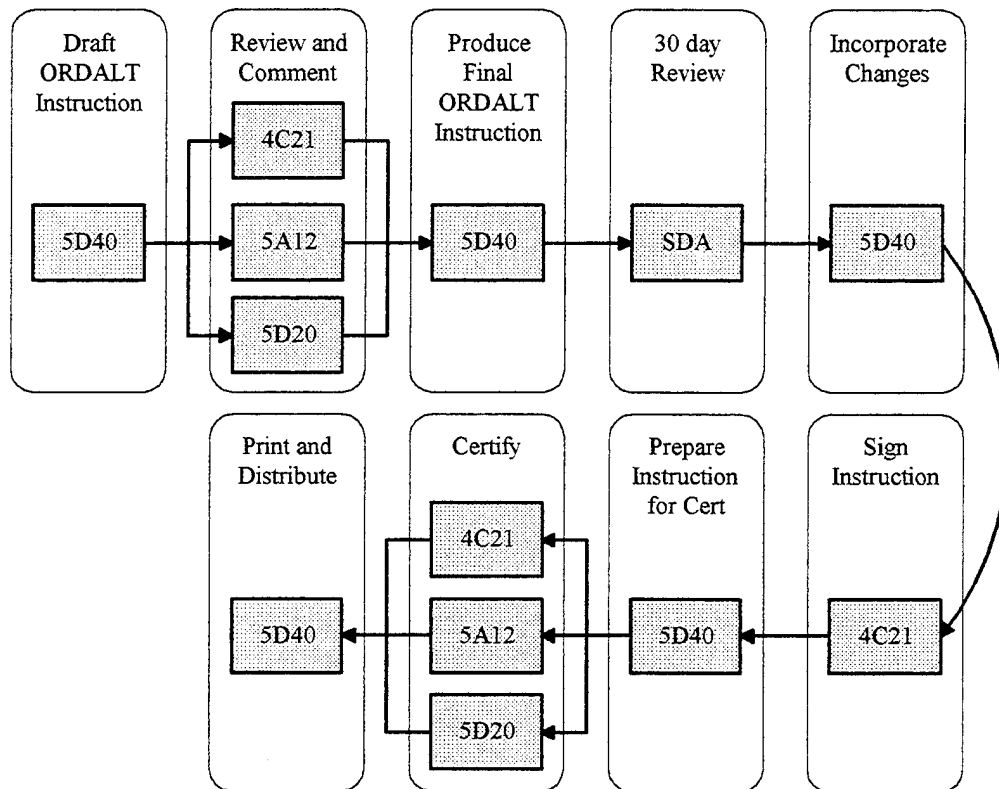


Figure 3-2. ORDALT Workflow - The current ORDALT workflow process has been partially automated through the use of IDMS.

responsible for reviewing the ORDALT for technical, logistical and maintenance implications to the system. While a review of the instruction is underway, members of Code 4C21 are concurrently installing the ORDALT on a test ship to ensure that the system is operational and engineered correctly. This is known as a proof-in.

Once the draft instruction has been reviewed, comments made, and the proof-in has been completed, Code 5D40 collects and incorporates the comments and prepares the ORDALT instruction for final review by the SDA. The SDA is authorized 30 days to review and make comments on the instruction. The comments are returned to Code 5D40 and, upon receipt, are incorporated into the instruction.

Next, the instruction is submitted to Code 4C21 for signature. Once signed by 4C21, it proceeds through the certification process in which the logistics parties involved (Codes 5A12, 5D20, as well as 4C21) sign that they are able to support the ORDALT. Once being certified as supportable, the ORDALT instruction is returned to Code 5D40 for printing and distribution. The signature page is faxed to the SDA. Once the SDA receives the signature page, the SDA then begins to print and distribute the ORDALT kits. This completes the process a typical ORDALT takes at PHD-NSWC. (Suwyn, 1994)

3. Technical Manual Change

Tech manual changes can be initiated in a variety of different ways. While all the initiation methods result in a change to a tech manual, the processes of each method are different. The process discussed here is a tech manual change initiated by a fleet unit via a Tech Manual Deficiency Report (TMDR). Figure 3-3 shows a TMDR as received from a fleet unit.

Upon receipt, the TMDR is passed to the NavSea Data Support Activity (NSDSA). Located at Port Hueneme, the NSDSA has the primary responsibility of receiving all TMDRs from the fleet and determining which In-Service Engineering Activity (ISEA) has the responsibility for acting on it. Upon assignment to the appropriate ISEA, the ISEA takes control over the completion of the TMDR request. In the case of the TMDRs for the Aegis weapon system, they are passed to PHD-NSWC Code 5D20 (See Figure 3-4). Code 5D20 has the responsibility for determining whether the TMDR is technical or non-technical in nature and which code within PHD is responsible for responding to the TMDR. In the case of an Aegis non-technical TMDR, it is passed to Code 5A12. In the case of technical TMDRs, Code 4C21 is given the responsibility. For the technical TMDR, Code 4C21 decides which internal division has the responsibility for the manual in question, and assigns an engineer to respond to the TMDR. Upon reviewing the TMDR and making any proposed changes to the tech manual, the TMDR and its recommendations are passed to Code 5A12. Figure 3-5 shows

R43550

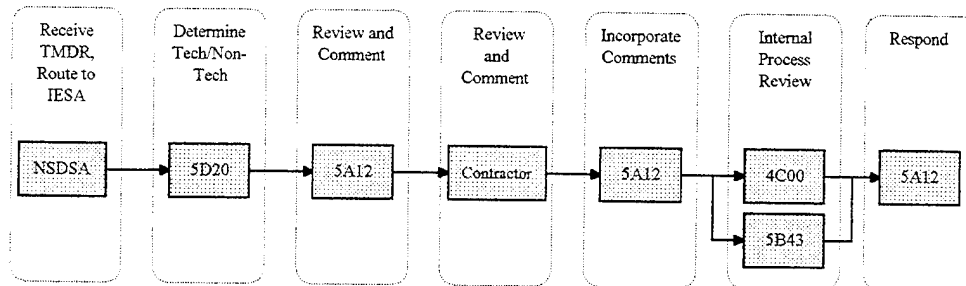
Insert Classif. of TMDR Here and At Bottom of Page: CLASSIFICATION: SECRET/NOFORN

NAVSEA (USER) TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT (TMDR) (NAVSEA 50005-AA-GYD-030/TMMP & NAVSEAINST 4160.3)					
INSTRUCTIONS: Insert classification at top and bottom of page. Read the following before completing this form. Continue on 8 1/2" x 11" paper if additional space is needed.					
1. USE THIS REPORT TO INDICATE DEFICIENCIES, USER REMARKS, AND RECOMMENDATIONS RELATING TO PUBLICATION.					
2. BLOCKS MARKED WITH "*" ARE TO BE FILLED IN BY THE CONTRACTOR BEFORE PRINTING.					
3. FOR UNCLASSIFIED TMDR'S, FILL IN YOUR RETURN ADDRESS IN SPACE PROVIDED ON THE BACK, FOLD AND TAPE WHERE INDICATED AND MARK (SEE OPNAVINST 5510.1 FOR MAILING CLASSIFIED TMDR'S).					
1. NAVSEA NO. *		2. VOL. PART *		3. TITLE *	
50005-AA-GYD-030/10 (G5E5B)				AEGIS COMBAT SYSTEM TECHNICAL OPERATIONS MANUAL FOR CG5E-CG5B	
4. REV. DATE OR TM CH. DATE		5. SYSTEM/EQUIPMENT		6. IDENTIFICATION/NUMERICAL CODE (MOD/ANI)	
15 MAR 92					
7. USER'S EVALUATION OF MANUAL (Check Appropriate Block)					
A. EXCELLENT		B. GOOD		C. FAIR	
<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
D. POOR		E. COM. PLETE		F. INCOM. PLETE	
<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
8. GENERAL COMMENTS					
RECEIVED 11 DEC 1994					
9. RECOMMENDED CHANGES TO PUBLICATION					
PAGE NO. A	PARA. GRAPH. B	LINE NO. C	FIG. NO. D	TABLE E	F. RECOMMENDED CHANGES AND REASONS
11-109			11-37		IN UPPER LEFT HAND CORNER M0T 2-412-2 (SF-4WSF-(2-412-2)(1)) IS LABELED (NORM) SHOULD BE (ALT) & ZSF-4WSF-(2-412-2) IS LABELED (ALT) & SHOULD BE NORMAL. CDSOS AND VISUAL INSPECTION VERIFY.
AEGIS TFBR/TMDR ACTION DATE FORWARDED: 12-16-94 NO. : R43550 CODE: 4022 DUE: 2-15-94					
10. ORIGINATOR AND WORK CENTER (PRINT)		11. ORIGINATOR'S RANK, RATE OR GRADE, AND TITLE		12. DATE SIGNED	
FEE JOHNSON, CGUS		ROBERTS, J.A. ENS. STO		2 Dec. 94	
13. SIGNATURE OF WORK CENTER HEAD		14. SIGNATURE OF DEPARTMENT OFFICER		15. AUTOVON/COMM NO. (24X)	
[Signature]		[Signature]		960-6520	
16. SHIP HULL NO. AND/OR STATION ADDRESS (DO NOT ABBREVIATE)					
(CG 58) FPO RA 34092-1178 (Philippine Sea) (2)					
17. THIS SPACE ONLY FOR NSDSA					
A. CONTROL NO.	B. COS/SEA	C. DATE	D. PRIORITY	E. TRANSMITTED TO	
R43550		RECEIVED	FORWARDED	DUE	4038
NAVSEA 50005/10 (REV. 6-88) S/N 9114-LF-020-8881 CLASSIFICATION: <u>SECRET/NOFORN</u>					
REPLACES 4-84 EDITION & NAVSEA 4160.1 (DESTROY STOCK)					
ENCLOSURE ()					

Figure 3-3. Technical Manual Deficiency Report (TMDR)- The TMDR provides the tech manual user input for change recommendations to a technical manual.

Tech Manual Change for Aegis Weapon System

Non-Technical Change



Technical Change

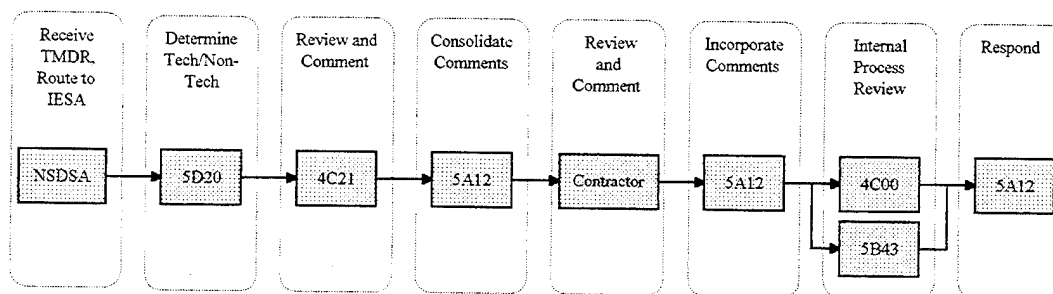


Figure 3-4. Tech Manual Change - Technical manual changes are classified as technical or non-technical

an example of the review and comment sheets that Code 5A12 receives from the other codes and consolidates into the change package.

Code 5A12 has the full responsibility for non-technical tech manual change requests and compiling and completing the change for technical requests. Code 5A12 sends a copy of the TMDR to the contractor responsible for the manual, or the code at PHD-NSWC that is responsible for the manual, who reviews the request and makes the appropriate comments. Code 5A12 incorporates the contractors comments. Once the comments have been made and the TMDR is ready to be answered, the recommended changes go through an Internal Review Process (IRP). The Internal Review Process brings together all the players in the TMDR process and ensures that the changes made are accurate. After the IRP, the recommended change is sent to the party responsible for the tech manual for inclusion in the next change printing. (Thaanum, 1994)

TECHNICAL MANUAL IN-PROCESS REVIEW (IPR) COMMENT SHEET			
CONTROL NO. 94-			PAGE / OF /
TITLE: EPT-18(Y) TRANSMITTER - MAINTENANCE DIAGRAMS			
CHANGE: 3-08-01 DATE ON DOCUMENT: 11/15/94			
REVIEWER: (NAME/ORG/COM) B. TRANMUR, PWO NSIC CODE 5843			
PAGE NO.	PARA/FIG/FIGURE TABLE NUMBER	COMMENTS	RESPONSE
	FOREWORD	<p>CHANGE WORD "THRU" TO "THROUGH"</p> <p>CHANGE "SECTIONS 1-11" TO SECTIONS 1 THROUGH 11</p> <p>CHECK TITLE ON COVER. IS IT PLURAL OR SINGULAR?</p> <p>CHANGE PWD NSIC ADDRESS TO: CODE 5800, 4343 MISSILE WAY ZIP CODE 95043-4307</p> <p>DROP OUT IN PWD A20, FAINT FILTER</p> <p>AGREE WITH ED FUNK'S COMMENT. THERE IS A LOT OF DROP OUT AND IS VERY HARD TO READ IN PLACES, SEE MARK UP.</p> <p>REMOVE PERIODS IN HVPS ON LEFT SIDE, MIDDLE (2 PLACES)</p> <p>REMOVE PERIODS IN HV ON LEFT BOTTOM OF DMG.</p> <p>1. CHECK MASTER FOR DROP OUT IN TOP LEFT SIDE, AND TOP MIDDLE</p> <p>2. REMOVE PERIODS IN HVPS IN 7 PLACES ON DRAWING (LEFT BOTTOM (2), CENTER BOTTOM (4), AND TOP RIGHT (1)).</p> <p>1. IN MIDDLE TOP, HV HAS PERIODS AND DIRECTLY BELOW IT THE WAS NONE. SHOULD ADD NEW DUES AS ALL OTHER TIMES THERE ARE PERIODS.</p> <p>2. REMINDER NOTES BECAUSE NUMBER 1 HAS BEEN REMOVED. REMINDER REFERENCES IN DRAWING.</p> <p>DELETE PERIODS IN HV AT TOP MIDDLE OF DRAWING.</p> <p>DELETE PERIODS IN HV AT TOP MIDDLE OF DRAWING.</p> <p>1. DELETE PERIOD IN HV AT BOTTOM LEFT OF DRAWING.</p> <p>2. DELETE PERIODS AT HVPS ON BOTTOM LEFT SIDE</p> <p>DELETE PERIODS IN HV ON TOP RIGHT CORNER</p> <p>CHANGE PAGE NUMBER TO 66-53/(66-54 BLANKS)</p> <p>1. DROP OUT IN HORIZONTAL LINES AT BOTTOM MIDDLE OF DMG</p> <p>2. DROP OUT IN 2ND "FAINT DROP" AT MIDDLE RIGHT SIDE</p> <p>DROP OUT ON TOP LEFT SIDE "INTEK OUT"</p>	
66-17	FIGURE 66-1		
66-21	FIGURE 66-2		
66-29	FIGURE 66-3, SH 4		
66-31	FIGURE 66-3, SH 5		
66-33	FIGURE 66-3, SH 6		
66-35	FIGURE 66-3, SH 7		
66-45	FIGURE 66-3, SH 12		
66-47	FIGURE 66-3, SH 13		
66-49	FIGURE 66-3, SH 14		
66-51	FIGURE 66-3, SH 15		
66-54.1	FIGURE 66-3, SH 16.1		
66-79	FIGURE 66-6, SH 1		
66-81	FIGURE 66-6, SH 2		

Figure 3-5. Review and Comment Sheet - Review and Comment sheets are used by the Tech Manual Workflows. The ECP and ORDALT processes now use IDMS to route the comments.

C. NEED FOR INCLUSION OF FLEET INTO WORKFLOWS

Hands-on, fleet experience and expertise in the maintenance and repair of sophisticated, finicky weapons systems have become a hard-to-find asset. With the downsizing in the military, the first billets to be deleted are the shore-based "support" technicians. PHD-NSWC is one of those commands that has sustained a loss of experienced uniformed personnel. The loss of those personnel has left the engineers at PHD without the end user perspective on the maintenance and repair of their cognizant systems.

In the workflows represented, interaction with the fleet unit is virtually non-existent. With the exception of fleet inputs initiating the tech manual change process and the use of a ship for the ORDALT proof-in, there is no consultation or concurrence with the fleet end user in the current work process of ECPs, ORDALTs, or tech manual changes. The work is completed entirely by the PHD engineers who for the most part do not have the fleet experience nor the perspective of the end-user whose equipment they are working on.

Of the workflows described above, the inclusion of the fleet unit could provide the PHD engineers with valuable information that could influence the planned decision or could save valuable time and money in ensuring a proposed procedure is valid and accurate. Only one of the workflows mentioned would not gain from having the fleet unit directly involved, and that is the non-technical technical manual change. These changes are normally typographical errors in which the concurrence by the fleet would be unnecessary.

1. ECP

Figure 3-1 showed the workflow for an ECP. Figure 3-6 indicates where the fleet input to the workflow solution could provide a sanity check for the engineer reviewing the proposal. This would help ensure that his calculations are correct and that there are no shipboard environmental issues involved with the ECP that could not be detected from the viewpoint of a shore-based engineer. The fleet could effectively provide inputs

ECP Workflow for Aegis Weapons System with Suggested Fleet Input

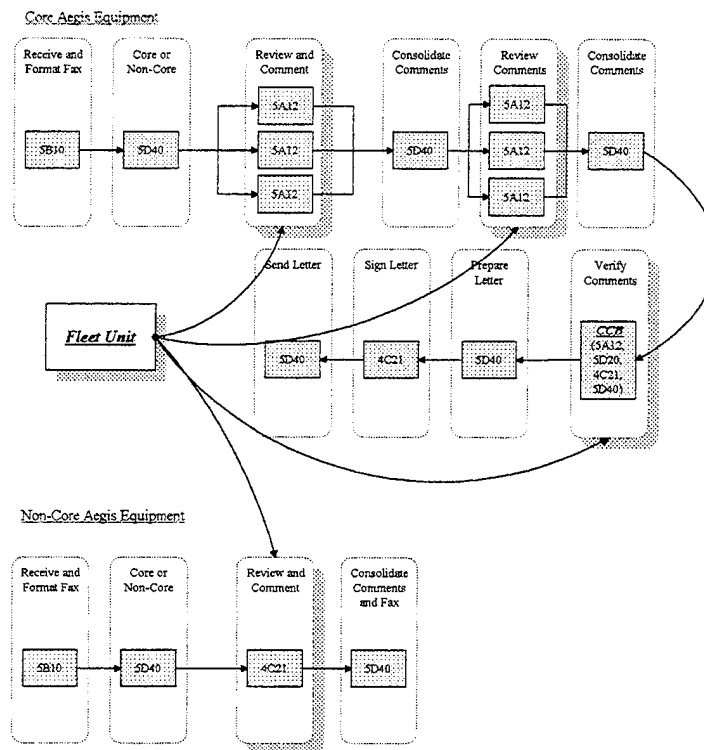


Figure 3-6. ECP workflow with suggested Fleet input

to both the review and comment portions of the workflow either as a full fledged reviewer or as a sub-reviewer under one of the engineers or logisticians. The unit could also act as a member of the CCB, providing the members of that body with insight that until now was unavailable. Whichever role the fleet would play, either as a full fledged member of the review team or the right-hand man of the reviewer, the experience and knowledge that the fleet unit could provide would be very beneficial.

2. ORDALT

In the ORDALT workflow, again the fleet unit could be a direct player or a subordinate player as in the case with the ECP. Again the best use of fleet input would be in the review and comment portion of the flow as either a primary or secondary

reviewer. The fleet could also play a role in the certification process, giving the ORDALT the fleet stamp of approval prior to it being issued and implemented. Figure

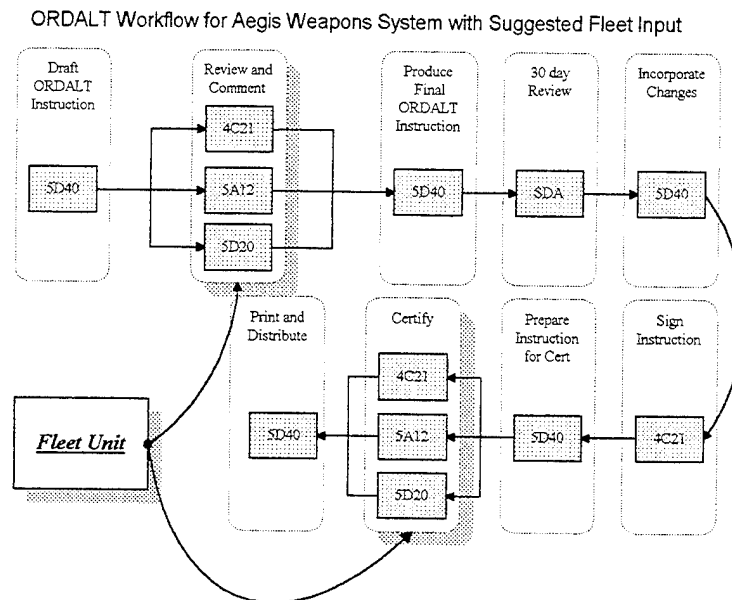


Figure 3-7. ORDALT workflow with suggested Fleet input.

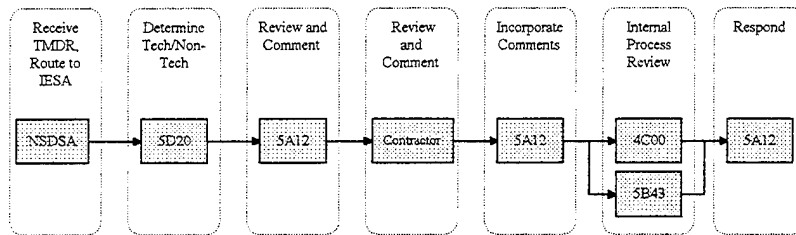
3-7 illustrates the role the fleet could have in the ORDALT workflow.

3. Tech Manual Change

The technical manual change workflow with the fleet input is reflected in Figure 3-8. As with the other discussed workflows, the most beneficial place for the inclusion of the fleet into the workflow is most probably the review and comment portion of the workflow. Although the workflow in this case was actually initiated by the fleet unit, the participation of a fleet unit in the workflow is still beneficial again, either as a primary or secondary source. As mentioned above, this would actually apply only to the technical tech manual change. A non-technical change would not require an input from the fleet because these requests are primarily for typographical errors.

Tech Manual Change for Aegis Weapon System with suggested Fleet Unit input

Non-Technical Change



Technical Change

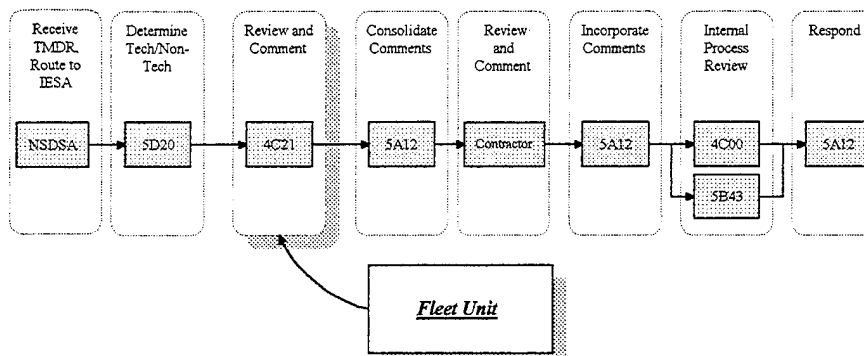


Figure 3-8. Tech Manual change workflow with suggested Fleet input.

IV. CONNECTIVITY OPTIONS TO THE FLEET

In order to bring the customer at a remote location into the workflow, connectivity to the customer's host or network must be established. For PHD-NSWC, the customer is the fleet and the requirement is to have the fleet integrated into the workflow at any time whether inport or at sea. Whereas providing land-based connectivity is now a routine task, providing data connectivity to sea is a relatively new challenge. Given the limited bandwidth of today's maritime communications technologies, it is even a greater challenge to exchange large-scale drawings between shore and ship.

This chapter will briefly describe the various methods of wide area connectivity that will enable PHD-NSWC to exchange workflow-related information with its remote customers, specifically fleet units. Details of the connectivity options that hold the most promise for the future, as supplied by the manufacturer, can be found in Appendices B-D.

A. FLEET CONNECTIVITY OPTIONS DIAGRAM

The various connectivity options are shown in Figure 4-1, with currently available technology on the left and technologies for the future on the right. Both sides of the diagram result in the connection of the PHD-NSWC IDMS host to the fleet unit whether at sea or inport.

B. WIDE AREA CONNECTIVITY

The first area of discussion is the connectivity options for the Wide Area Network (WAN). As shown in Figure 4-2, the WAN is the long-haul path connecting the PHD-NSWC Local Area Network (LAN) with the homeport or shore facility of the fleet unit. There are currently numerous options for WAN connectivity either military or commercial. In DoD alone, the "stovepipe" systems of the past have resulted in many different systems all providing essentially the same types of services. Today, the push is underway to consolidate those various methods into one centrally managed system.

Fleet Connectivity Options

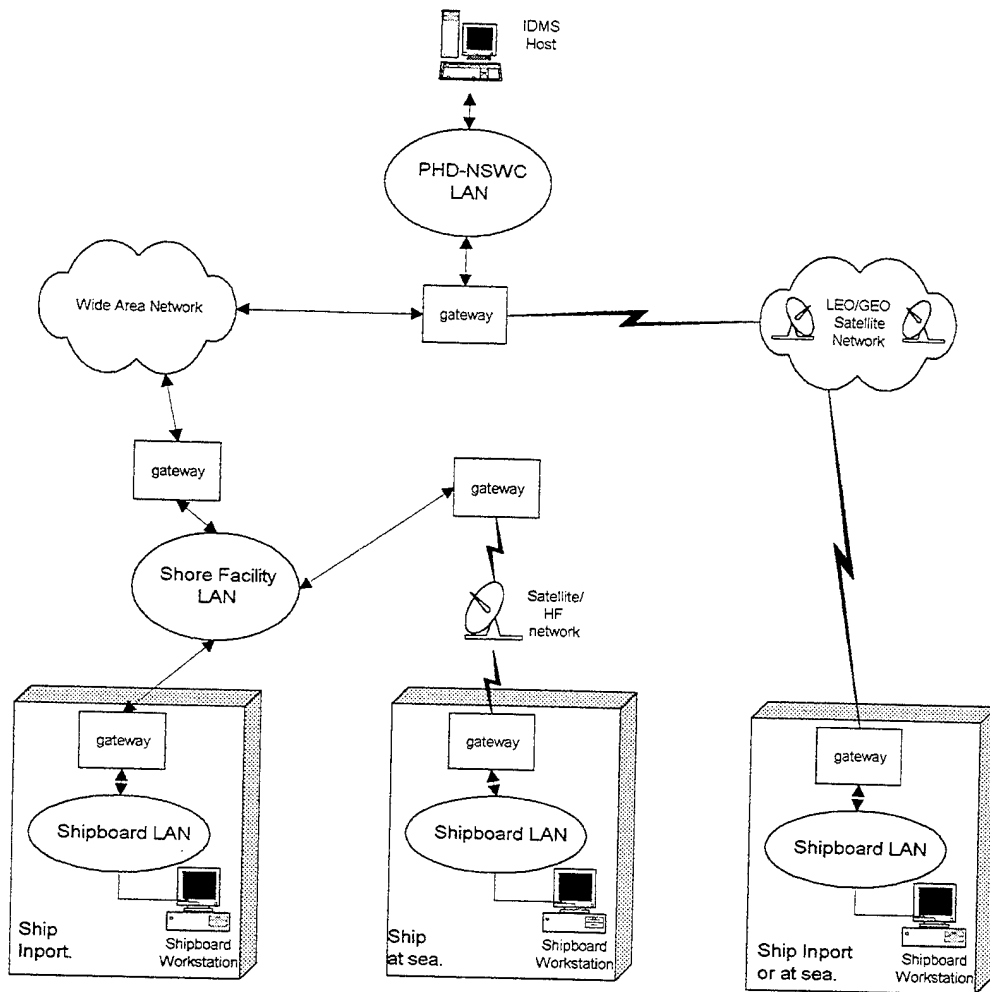


Figure 4-1. Fleet Connectivity Options - Connectivity to the fleet can be conducted via the terrestrial WAN or via tomorrow's satellite based WANs.

1. FTS2000

Federal Telecommunications System 2000 (FTS2000) was established in December 1988 to provide long-haul communications for all government agencies. FTS2000 is managed by the General Services Administration (GSA), and consists of two major contracts that divide communications services into an "A" network serviced by

AT&T, and a "B" network serviced by Sprint. GSA is the entity that actually assigns specific agencies to either the "A" or "B" networks. (Data Communications, 1993, p.92)

FTS2000 provides the following basic types of services:

- ♦ Switched Voice Service for transmitting voice and data at rates up to 4.8 Kbps;
- ♦ Switched Data Service for dialed-up end-to-end digital data transmission at 56 Kbps and 64 Kbps;
- ♦ Video Transmission Service for compressed video and full motion teleconferencing;
- ♦ Packet Switched Service for transmitting data in packet format;
- ♦ Dedicated Transmission Service for point-to-point private line service from voice grade analog up to T1 service; and
- ♦ Switched Digital Integrated Service (SDIS) for a combination of services using T1 or Integrated Services Digital Network (ISDN). (DIA, 1991, p.6-34)

FTS2000 was intended to last 10 years and has survived occasional congressional challenges to find alternatives. The FTS2000 contracts are due to expire in December 1998. (Masud, 1994, p.3)

LAN-to-LAN Connectivity through a WAN



Figure 4-2. LAN-to-LAN Connectivity through a Wide Area Network (WAN) - A variety of WAN are available to interconnect LANs over a large geographical region.

The FTS2000 backbone consists of service nodes (switches) that are interconnected by T3 (44.7 Mbps) fiber-optic links. Users access FTS2000 via Service Delivery Points (SDP's) located at the customer's location. The interface that provides access to FTS2000 can be a private branch exchange (PBX), or other customer-owned equipment. (DIA, 1991, p.6-34)

2. DCTN

The Defense Commercial Telecommunications Network (DCTN) is the largest DoD common-user network. It is a command and control network established in March

1986, through a ten year contract with AT&T under the management of the Defense Communications Agency (now DISA). The following attributes are considered integral DCTN features:

- ♦ integrated voice, data, and multi-point video in a digital network;
- ♦ single point of contact for end-to-end service with centralized operation and maintenance;
- ♦ integrated, centrally controlled, all-digital network;
- ♦ reconfigurable network capacity to meet user demand;
- ♦ secure transmission via digital encryption standard (DES);
- ♦ protection of satellite links for network privacy;
- ♦ integral part of the Defense Switched Network (DSN). (DIA, 1991, p.6-16)

DCTN was originally used as an interservice communications link to support various components or communities of interest within the DoD that required frequent interactive high-speed data transmission. The first DCTN user was the Army Material Command in 1986. It was shortly joined by the Air Force Logistics Command, Air Force Systems Command, Headquarters Department of the Army, Army Forces Command, Naval Air Systems Command, AEGIS Navy Command and the Strategic Defense Initiative (SDI) Command. Originally a satellite based network, as land-lines became more abundant and more affordable, the network evolved from satellite-based to its current state of primarily using terrestrial-based fiber-optic links. The current DCTN contract is scheduled to expire in March 1996. It will most probably be extended on a month per month basis until it is fully replaced by the Defense Information System Network (DISN).

3. NAVNET-IP

NAVNET-IP is a common user network that provides synchronous and asynchronous connectivity to the global Internet and DoD networks such as MILNET, NSFNET, PILOT-NET AFIN, and DLANET. Originally, a low speed circuit network, NAVNET-IP was established by the Naval Computer Telecommunications Command (NCTC) to provide long-haul circuit integration for Navy users. Evolved from the Data Automation Command Network (DACNET), NAVNET-IP provides both dial-up and dedicated connections up to T3 on lines leased from DCTN. Technically, the

NAVNET-IP contract expires with the expiration of the DCTN contract in March 1996. At that time, NAVNET-IP will be merged into the DISN network.

NAVNET-IP services are divided into three basic categories:

- ♦ Packet-switched users of the Defense Data Network (DDN),
- ♦ Full-period users -- dedicated (24 hour) bandwidth, and
- ♦ Video teleconference users.

NCTS Pensacola has been designated by the Defense Information Systems Agency (DISA) as a Level II Network Management center for the DISN/NAVNET-IP router network. As a level II facility, they provide full inter-networking support. They are chartered with providing provisioning, maintenance, technical assistance and network management services including the procurement, installation, maintenance, and management of the material required to establish connectivity. (NCTS Pensacola, 1995)

4. DDN

The Defense Data Network (DDN) is a worldwide digital packet switched long-haul network. Operated by the Defense Information Systems Agency (DISA), the DDN is designed to meet the needs of DoD for both a secure command and control, communications network and for ordinary unclassified communications.

The DDN enables computer systems and terminals/workstations acquired from different manufacturers to exchange information. Providing near worldwide coverage, the DDN supports military operational systems including the World-Wide Military Command and Control Systems (WWMCCS) and intelligence systems, as well as general purpose ADP and command-based data networks with long-haul communications requirements. Established in 1982 as the DoD common user data communications network, DDN was based upon ARPANET packet-switching technology. The DDN currently consists of four separate networks operating at different levels of security:

- ♦ MILNET (Unclassified);
- ♦ DSNET 1 (Secret);
- ♦ DSNET 2 (Top Secret);
- ♦ DSNET 3 (SCI);

5. DISN

In June 1993, The Chairman of the Joint Chiefs of Staff (CJCS) ordered the establishment of the Defense Information System Network (DISN) with the original objective to achieve a single DoD worldwide common user IP router network. The CJCS directed all DoD Service/Agencies to use the DISN as the primary WAN for all DoD long-haul common-user telecommunications services. The DISN is defined to include switched voice and data and is centrally managed by DISA.

The DoD currently operates several router-based WANs. While seemingly cost effective when viewed individually, from the collective DoD perspective, they are duplicative. Since all these networks support sizable user bases, service could not be disrupted while transitioning to a new and improved infrastructure. Consequently, the Air Force Internet (AFIN), Navy Internet Protocol Router Network (NAVNET-IP), and other currently operational DoD wide area router networks will have to continue to exist until such time as they can be evolved into a single DISA centrally managed, data service infrastructure.

Currently, the DISN data service is composed of 86 hub routers, formerly the Defense Logistics Agency Corporate Network (DCN), and ten routers that provide the interconnection service for the DoD and non-DoD router networks, formerly the DDN Pilot Internet. The Unclassified but Sensitive IP Router Network is the NIPRNET. The routers are located primarily throughout CONUS but plans are in progress to extend service to the European and Pacific theaters. Currently, the DISN unclassified data service is centrally managed by the DISN Level II Network Management Center (NMC), Columbus, Ohio. Plans are in place to expand the network management capability to the out of CONUS theaters as required. The DISN is supported by the network management staff 24 hours daily, 7 days per week. The DISN Level I NMC provides policy, management, oversight and problem resolution support to the DISN Level II NMC. Maintenance is currently provided via 3rd party maintenance under existing maintenance

contracts. DISN is supported by the Defense Business Operating Fund (DBOF) and operates under a cost recovery scheme. (DISA, 1994)

6. Commercial Internet Providers

Commercial Internet Providers are also available to provide "Internet" connectivity to units pierside and other fixed locations. Most metropolitan areas now have full service internet providers that can furnish connectivity ranging from 9600 bps dial-up service to T1 and greater dedicated lines. Services that these companies provide include:

- ♦ Access -- enabling customers to fully access the Internet's numerous resources;
- ♦ Training -- helping customers to most effectively utilize the Internet;
- ♦ Consulting -- meeting the specialized Internet needs of their customers; and
- ♦ Information Provision -- information is made available world-wide about the customer's businesses and organization.

These Internet providers are able to supply these services for individuals as well as large organizations. Some examples of providers are *Portland Internet Corporation*, providing service to the Portland, ME area, *USA OnRamp*, a service provider in the Pittsburgh, PA region, and *CallAmerica* which services the Central California area. While the services of the commercial Internet providers are necessary for the general public, the services that they provide would not be any more beneficial or cost effective than that provided by the DoD supported connections previously discussed.

C. CONNECTION TO INPORT SHIP

The discussion above described the methods for connecting PHD-NSWC to the local homeport through the WAN. The next step in the discussion of establishing connectivity to the fleet unit will center on connecting the ship to the local shore facility's Local Area Network (LAN) while inport. Essentially, there are two methods for connecting the ship to the local LAN while the unit is pierside, via a hard wired connection, or through the use of a wireless service.

1. Wireline Connectivity

Wireline connectivity is probably the easiest and most cost-effective method for connecting the ship to the base LAN. (See Figure 4-3.) Depending on the base infrastructure, coax or fiber cable could be run to the pier and connected to a gateway unit onboard the ship, connecting into the ship LAN. This would not only provide the fleet unit the ability to receive workflow routing from PHD-NSWC, but it would also provide the unit with access to base facilities such as Ship Intermediate Maintenance Activity (SIMA), Personnel Support Detachment (PSD), Family Service Center (FSC) and the Squadron Commander (DESRON).

Ship-to-Shore LAN Connectivity through a Wireline Connection

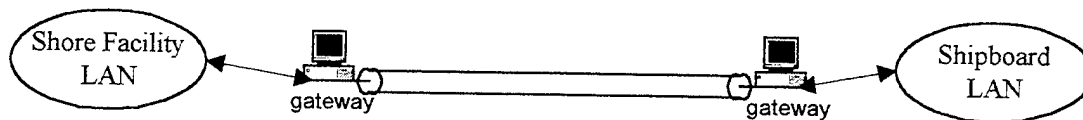


Figure 4-3. Ship-to-Shore LAN connectivity through a Wireline connection - Wireline interconnectivity of LANs can be done through copper wire or fiber optics.

2. Wireless Connectivity

Wireless connectivity can be broken down into two different categories. First, the use of wireless data services can be used to connect the unit directly into the WAN (See Figure 4-4), an option to be considered depending on the status of the local base

Ship-to-Shore LAN Connectivity through a wireless service connected directly into the WAN

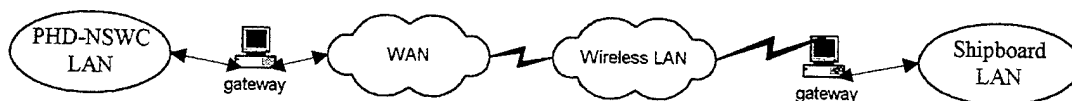


Figure 4-4. Ship-to-Shore LAN Connectivity through a Wireless Data Service conneted into the WAN.

infrastructure. Secondly, wireless LAN technology can be used to connect into the base LAN in the same manner as with wireline method (Figure 4-5).

Ship-to-Shore LAN Connectivity through a Wireless LAN



Figure 4-5. Ship-to-Shore LAN Connectivity through a Wireless LAN.

a. DataTAC/ARDIS

The DataTAC system is Motorola's wireless data communications system used traditionally for motor fleet dispatch and management, but with the capability to do more. With DataTAC, the capability to conduct database inquiries from central computers, submit electronic reports, send e-mail, and conduct file transfer is all possible. The system uses an advanced Radio Data Link Access Procedure (RD-LAP) radio channel protocol to provide data rates up to 19.2 kbps. While this system does not afford worldwide connectivity, through the ARDIS network, it provides coverage across the US. The ARDIS network is the largest shared wireless network in operation today serving approximately 40,000 users. Although a land based system, it may be suitable for use in a battlegroup setting where the data can be transmitted via other means to the carrier or flag ship and then distributed to the other units in the group via an ARDIS type network. However the low data rate of this system may also preclude its use for PHD-NSWC's purposes. (Kenward, 1994)

b. CDPD

Cellular Digital Packet Data (CDPD) is the technology used to transmit data across cellular telephone networks. CDPD is a digital data transmission system that overlays existing analog cellular networks. The system operates at 19.2 Kbps per channel. CDPD provides maximum connectivity by using idle times between cellular

voice calls or transmitting in a dedicated channel environment. Developed by a group of cellular carriers as a detailed specification for a data service, CDPD is gaining favor over other cellular data technology because of its robustness. CDPD was designed to be reliable, interference free and secure. Its data transmission technology is efficient, using the bandwidth not utilized by voice, and it utilizes much of the cellular infrastructure currently in place for the voice network, allowing for quick implementation and reduced network costs. CDPD technology is being incorporated into most of the major cellular carriers. Its use for incorporating workflow to PHD-NSWC's customer would have the same limitation as the DataTAC implementation, limited range and low datarate. (McCaw Cellular, 1994)

c. Wireless LAN

A wireless LAN is a LAN that uses a wireless medium to connect computers in a LAN. There are basically three technologies available for a wireless LAN: narrow-band radio frequency (RF) transmission, spread spectrum RF transmission, and light-based transmission (infrared).

The single frequency or narrowband radio systems are relatively old technology. They operate in the VHF/UHF spectrum, and the Federal Communications Commission (FCC) requires a license to operate the narrowband transmitter required for these systems. Licensing is required to ensure that the proposed frequency usage will not interfere with another system such as local radio and television stations that operate in similar frequency ranges. Once obtaining a license, the frequency assigned is dedicated, and any interference received by other parties is handled by the FCC.

Spread spectrum also uses radio transmission, however in a different manner. Spread Spectrum technology is a technique for uniformly distributing the information content of a data signal over a frequency range considerably larger than that normally required for robust transmission of data. (Heiman, 1991) The advantage of spread spectrum signals is that the possibility of interference is greatly reduced because the data is spread over a wide range of the available spectrum. This allows the signal to

be transmitted with much less power, and allows the capability of two or more systems to operate in the same frequency range due to the use of spreading codes that would appear invisible to the other systems. As such, the FCC has provided three frequency bands for unlicensed spread spectrum applications, including wireless LANs. Two of the leading Spread Spectrum Wireless LANS are NCR's WaveLAN, and Windata's FreePort.

The third technology employed in wireless LANs is Infrared. Infrared technology provides a high degree of bandwidth, allowing it to carry hundreds of megabits of data per second (Carr, 1991, p.23-24). Advantages of infrared include the lack of a licensing requirement, and the lack of RF interference. The disadvantage is that Infrared requires line-of-sight in most cases, and cannot penetrate walls or objects as the RF technologies can. (McBee, 1993)

D. CONNECTION TO AT SEA SHIP

The next step in the discussion is the methods currently available for connecting the fleet unit to the shore based infrastructure while at-sea (See Figure 4-6). Currently a few methodologies exist for the transfer of information while at sea. HF, SALT/INMARSAT, and Milstar are the current systems that provide data transfer capabilities although they are limited in either available bandwidth or system availability.

1. HF

New advances in High Frequency (HF) technology has made the use of HF as a data carrier competitive with many of the upcoming LEOs systems in capacity and

Ship-to-Shore Connectivity through HF or an Existing Satellite System

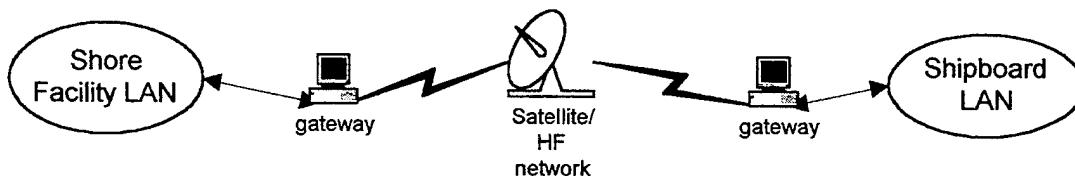


Figure 4-6. Ship-to Shore Connectivity through HF or an Existing

coverage. The latest advances in HF radio technology make the use of HF worth considering for low data rate connectivity. Recent advances in modem technology and automatic frequency selection have given new life to the once thought dead art of HF communications. Currently the HF link is able to establish 4800 bps connectivity with ongoing work being conducted to improve this capability to 9600 bps. Demonstrations are in progress to demonstrate the use of HF as a carrier for battle group e-mail support and as an extension of the SHF SATCOM network to units without SHF SATCOM capability. This may make it an option to consider for e-mail and small scale workflow applications. (Olson, 1994)

2. SALTS/INMARSAT

The Streamlined Automated Logistics Transmission System (SALTS) was developed as a result of the Gulf War. Connected through the INMARSAT commercial satellite system terminals, reservists at the Navy Aviation Supply Office developed SALTS as a bulletin board system to transfer logistics data to and from deployed units. As a result of its solid performance, SALTS has become the standard for all ships using INMARSAT to transmit and receive logistics data. SALTS provides access to the following networks: the Defense Automated Addressing System, Defense Data Network, Navy Logistics Network, Marine Corps Data Network, NAVNET-IP, and Internet. SALTS is accessible through INMARSAT, SHF, DDN, FTS 2000, and commercial telephone systems including cellular telephone. Through SALTS, ships can receive and transmit logistics data, financial reports, payroll data, personnel data, and e-mail to other systems. (Walters, 1993)

INMARSAT is a 4 GEO satellite, 31 earth station communications system providing full earth coverage below 76° latitude. Managed by the International Maritime Satellite Organization it is chartered to be used for "peaceful" purposes only. DoD contracts with COMSAT, the US representative to INMARSAT, to provide access to the INMARSAT system through COMSAT's earth stations in Southbury, CT, Santa Paula, CA and Anatolia, Turkey. Communications services available through INMARSAT

include telephone, telex, fax and data transfer services. The standard shipboard installation can handle up to 9600 bps data transmission and can be upgraded to 56 Kbps with the addition of additional equipment. (Walters, 1993) The benefit of the SALTS/INMARSAT system is that almost every US Navy ship is outfitted with the an INMARSAT system and therefore able to use SALTS.

3. MILSTAR

The Milstar system was established in conjunction with the Defense Satellite Communications System (DSCS) to be one of the core Department of Defense Military Satellite Communications (MILSATCOM) architectures. Milstar is a joint satellite communications system designed to meet the minimum wartime communications needs of the National Command Authorities, theater Commander in Chiefs, and strategic and tactical forces. (Jain, 1990) The objective of Milstar is to develop and deploy an affordable terminal and satellite system with low probability of intercept and anti-jam, providing long-haul and local communications. Although primarily a voice network, the Milstar system does have a low data rate capability and, with the launch of the Milstar II satellites at the end of the century, data transfer up to 1.5 Mbps will be available. With only one satellite currently in the inventory, it is too early to tell what the use and general capability the Milstar system will provide. In addition the current implementation of Milstar requires a dedicated Milstar terminal and may not be compatible with shipboard LANs. (DIA, 1991)

E. FUTURE CONNECTIVITY OPTIONS

The promise for a high-bandwidth at sea connection clearly lies in the development of future systems. All of these future systems will rely on the use of satellites to directly connect the PHD-NSWC LAN with the fleet unit LAN bypassing the need for the terrestrial based WAN (See Figure 4-7). These future satellite based systems fall into two types, the traditional Geosynchronous Earth Orbit satellites and the up and coming Low Earth Orbit satellite systems. Many of these systems mentioned are research-oriented and thus experimental in nature. However their results are being put to use in

systems under development by both DoD and commercial interests and warrant consideration in this discussion.

1. Geosynchronous Earth Orbit (GEO)

A Geosynchronous Earth Orbit Satellite hovers over a spot on the equator at the altitude of 22,300 miles. GEO satellites have been in existence since the early 1960's

LAN-to-LAN Connectivity through a Satellite WAN

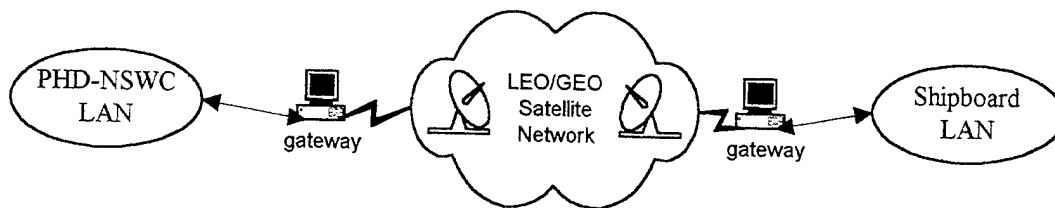


Figure 4-7. LAN-to-LAN Connectivity through a Satellite WAN. New LEO and GEO systems have the potential to radically change the way communications are conducted within DoD.

when the NASA Syncom program demonstrated the operational feasibility of communications at a geostationary orbit. (Vondeak, 1994) Existing INMARSAT, FLESAT, INTELSAT and COMSAT satellite systems are examples of both commercial and military GEO systems.

While the use of geosynchronous satellites for the purpose of communications is commonplace today, there are quite a few shortcomings in their use. GEO satellites require that users have large transmitters and large steered antennae due to the distance the satellites are from the Earth. GEO systems can only provide regional vice global coverage due to their location centered above the equator. This is especially true in the upper latitudes ($>70^\circ$) where most GEO systems lose their capabilities. Additionally, due to lack of demand, many of the commercial GEO satellite systems provide poor coverage of the maritime region. Another drawback for the GEO systems is that they are predominately voice, circuit switched. The ability to transfer data is extremely limited, in most cases to 2400 bps although newer SHF systems now are boasting capability to deliver T1 data capacity. Another big problem for the GEO systems, especially in the

world of computer communications is the propagation delay. The 1/3 to 1/2 second delay in the relay through the satellite and back would have profound effects on the ability to conduct interactive multimedia applications.

Another problem for the GEO systems is the mentality of the parent organization. Being the "old guard" of the satellite world, the GEO providers are reluctant to look at alternative methods for conducting space based communications. This near-sightedness may come back to haunt these companies as newer, upstart participants join the market.

While there are problems inherent with GEO satellite systems, advances in their use for data communication have proceeded at a rapid pace. Below are some of the currently active players in the data transmission area for GEO satellite systems.

a. ACTS

The National Aeronautics and Space Administration (NASA) Advanced Communications Technology Satellite (ACTS) Program is developing a variety of new satellite communication technologies and, through its Experiments Program, promoting the applications that will use this technology. Examples of the developmental technologies include 30/20-GHz components, 110 Mbps time-division multiple access (TDMA), on-board digital signal regeneration and switching, and multibeam antennas. Although this is a research program and ACTS will not have any direct bearing on the bringing of workflow to the fleet, the advances in technology made here will be incorporated into the systems of the future and therefore gives us the ability to get a view of the future. (Vondeak, 1994)

b. MONET

The High Data Rate MObile InterNET is a testbed of high data rate tactical communication technologies for the DoD that will support voice and video teleconferencing, imagery and other forms of data. It will incorporate new applications using commercial standards such as the Asynchronous Transfer Mode (ATM), and the Synchronous Optical Network (SONET), high data rate military radios, and DoD and commercial satellite communication (SATCOM) links. MONET will extend the shore

based Defense Information Systems Network (DISN) to serve joint forces deployed within a theater of operations and will combine elements developed by the Navy at NRaD San Diego, the Air Force at Rome Laboratory, New York, the Army at CECOM, New Jersey, and testbeds operating at other DoD facilities and their contractors. The goal is to provide a network capable of T1 or higher aggregate data rates. Monet is a research project and therefore is not available for use by end-users. However, as with the ACTS system, it has been included here because results of the ongoing research will be incorporated into other implementation projects. (NRaD, 1994)

c. SPACEWAY

Spaceway is Hughes Communications' answer to the threat of the oncoming LEO systems. Originally designed to provide coverage over the US only with two satellites, current plans are for worldwide coverage using 4 GEO satellites. Spaceway was designed from the onset to be a complement to the efforts being undertaken with terrestrial information infrastructure. The system intends to offer voice, data and video services. (Gilder, 1994) Spaceway will offer bandwidth on demand services ranging from 16 Kbps to 2 Mbps or higher. Access to the system will be via a two-way 26 inch antenna. Designed to seamlessly integrate with existing terrestrial infrastructure, Spaceway is marketing its services to offer a wide variety of business applications including desktop video, telephony, and conferencing, computer networking, technical tele-imaging, CAD/CAM transmission and high-speed, low-cost access to the next generation of on-line multimedia databases. (HCI, 1994) Additional information on the Spaceway system can be found in Appendix B.

2. Low Earth Orbits (LEO)

The Low Earth Orbit satellite systems are new and currently yet unfielded. Regardless, the promise they hold has the capability to revolutionize the communications world much the same way the telephone did at the turn of the century and the way the personal computers networks are doing today, and are greatly affecting the satellite balance of power. (Gilder, 1994) However, since they have yet to be deployed and have

not been able to show if they are capable of delivering what is promised, their true impact will have to be seen. The LEO's have a number of advantages over the GEO systems, among them are distance, coverage and capability. Due to the relatively close-in distance, LEO satellites have an advantage over GEO's of about 25 dB of power. To the mobile user, this means that omni-directional antennae can be used, which on ships means that steered dishes would not be required. Also, with the reduction in the need for power, the size of the transmitter can be reduced resulting in savings of space and weight or an increase in the number of transmitters available.

Not all LEOs plan polar orbits, but most do. Polar coverage provides the high latitude coverage that GEOs do not provide for. This is specially important for those units operating in areas above 70 degrees latitude.

The capabilities the LEO systems promise are impressive. In addition to their primary function of telephone, paging, or data transfer, they can provide Radio Determination Satellite Services (RDSS) positioning directly or can provide differential GPS data paths.

The current downside to the LEO systems is interoperability. All of the satellite vendors (GEOs included) are scrapping over compatibility issues (mostly dealing with limited spectrum). None of the vendors discuss interoperability, either with each other or with existing data networks (with the exception of Teledesic).

A number of LEO companies have recently received licenses from the FCC to build and operate their systems. Included below is a brief summary of the most prominent of the systems currently planned for implementation. All the systems except for two plan to offer simple two way messaging, paging and tracking. One has designated itself as solely a space-based cellular phone company, and one has been expressly designed as a data communications service.

a. Orbcomm

Designed as the world's first wireless, two-way data and message communications system providing coverage everywhere on Earth, Orbital

Communications' Orbcomm recently received FCC License for a 36 satellite constellation. Planned launch date for first satellites is March or April of 1995. The systems foundation is its LEO satellite system. Consisting of 36 satellites, four gateway earth stations in the US, one Network Control Center and one Satellite Control Center, Orbcomm plans worldwide service by 1998. (It will require a gateway earth Station and Satellite Control Center in each country desiring service) Orbcomm communications service is a digital packet switching, VHF system using two main frequency bands for satellite uplinks and downlinks. The network is accessible through dial-up circuits, public e-mail services or any X.25 (packet switched) circuit. The satellite is a non-voice, non-geostationary satellite located at an altitude of 775 km. Coverage in the 48 contiguous states is intended to be greater than 93%, with maximum outages to be on the order of 5 minutes or less, 90% of the outages to be less than two minutes. (Orbcomm, 1994)

b. Globalstar

Globalstar, a joint venture between Loral and Qualcomm, will offer worldwide mobile voice, data, paging, messaging, and RDSS to and from efficient hand-held and vehicle mounted transceiver terminals, regardless of location. Globalstar's terminals, hand-held units in particular, are small, state-of-the-art designs, operated in the same manner that a user would operate today's wireless cellular telephones. The system's mobile terminals are equipped with omni-directional antennas, eliminating the need to be pointed at a satellite to achieve and maintain reliable linkage.

The Globalstar system is composed of 48 LEO satellites, operating through gateways in conjunction with existing terrestrial networks. Working as "bent pipes," all calls are set up and processed on the ground by the local gateway terminal. Gateway equipment consists of hardware, software and a packet switched data network for operational control, roaming access and other administrative functions. Gateway stations provide interconnections to public switched telephone networks (PSTN). Each satellite has the capacity for a minimum of 2800 duplex voice or data circuits. Orbit

selection and the use of CDMA spread spectrum technology increases the number of circuits over a region with multiple satellite coverage. A large number of users can receive service simultaneously all over the world. (Globalstar, 1994) More information on Globalstar can be found in Appendix C.

c. Iridium

Iridium is Motorola's \$3.4 billion worldwide satellite based cellular telephone system. Iridium's constellation will include 66 satellites in eleven nearly polar orbits (tilted 86 degrees) 420 miles out. The Iridium system's satellites will blanket the globe. All the satellites will be crosslinked, whereas the others are bent-pipe satellites that feed the signals to a ground station for processing and into land lines. In addition to stand-alone telephony, the Iridium system will connect through ground-based gateways into the local Public Switched Telephone Network (PSTN). The Iridium system uses Time Division Multiple Access (TDMA) as its frequency division scheme. To use TDMA, Iridium has demanded exclusive rights to a segment of the spectrum (in addition to the 200 MHz of spectrum for its satellites to talk to each other). This plus the fact that the data transfer capabilities for the system are limited deducts from the attractiveness of this system. (Iridium, 1995)

d. Teledesic

A joint venture anchored by Microsoft's Bill Gates and McCaw Cellular's Craig McCaw, Teledesic proposes a global network of LEO satellites to deliver a wide array of broadband information services. The only LEO system dedicated to computer communications, its intention is to establish a "global wireless internet". The system will be able to provide bandwidth on demand ranging from 16 Kbps up to 2.048 Mbps and for special applications up to 1.24416 Gbps. The system transmits and receives in the Ka-band (30/20 GHz). It employs a high mask angle to avoid high rain and terrain attenuation. Its proposed 840 active satellites plus 84 spares on 21 orbital paths staggered in altitude between 695 and 705 km "interlinked into a robust geodesic network topology" is the most ambitious of the LEO endeavors. Each of the 840

satellites contains a fast packet switch, based on ATM and B-ISDN technology, to route packets to their destination along the path of least delay. The network can realistically support 20 million users if the system was devoted to narrowband voice. Unlike the other LEO's it will operate as a non-common carrier, and will not market its services directly to end-users. Rather it will provide an open platform for service providers in the US and host countries to bring affordable internetwork access to rural and remote locations. Much of the technology used in the Teledesic project represents the first use of the defense department research "brilliant pebbles." Teledesic will provide 24 hour seamless coverage to over 95% of the earth's surface and almost 100% of the Earth's population. (Teledesic, 1994) Additional information on Teledesic can be found in Appendix D.

e. Odyssey

Technically not a LEO, TRW's Odyssey is brought into the LEO fold because it defies the traditional GEO architecture. Featuring 12 high-flying MEO birds (4000 miles) that use inertial guidance systems to point themselves, focusing their beams at their selected continents, these satellites provide "bent pipe" coverage to the ground station where all the processing and connection into the PSTN are done. Proponents of this system state that it combines the low power requirements of the LEO systems with the low satellite requirements of the GEO systems. The primary function of the Odyssey systems will be voice communications, with limited capability to provide paging, fax, voice and limited data capacity. (TRW, 1994)

V. RECOMMENDATIONS AND CONCLUSIONS

In Chapter III the need to have the fleet unit integrated into the division's workflow was determined. Chapter IV reviewed various connectivity options, both currently available and under development, for interconnecting fleet units to PHD-NSWC. It was noted that only a few services could provide a connectivity to fleet units at sea and, due to limited bandwidth, none of these would be suitable for the transfer of large-scale engineering drawings. This chapter will provide the recommendations for PHD-NSWC to follow in the incorporation of the fleet unit into their workflow given such constraints.

The recommendations are based on a review of the systems available for use today and do not provide an implementation plan nor a cost benefit analysis. They are solely based on the need to establish a high-bandwidth connection and methods that are capable of providing it. The recommendations are made with the following assumptions.

- ♦ PHD-NSWC does not have the funds to create its own infrastructure for WAN connectivity; therefore existing "Internet" connectivity methods will need to be relied on.
- ♦ All ships will become networked within the next few years. In those cases where the ship is currently not networked, a separate PC on the unit would have to be modified to accept the connection.
- ♦ The systems required a minimum of 56 Kbps to be considered for PHD's use. 56Kbps is the minimum standard for the DISN WAN architecture and should therefore be adequate for the transfer of large-engineering drawings (although higher bandwidth is desired.)
- ♦ Both military and commercial efforts in the area of shipboard and worldwide WAN connectivity will continue to progress.

On the basis of current technology available, the following course of action is recommended to be taken by PHD-NSWC:

1. Current technology option: Implement a shore based connection to the unit's homeport.
2. Future technology option: Plan for the use of a satellite based system upon initial operational capability (IOC).

A. CURRENT TECHNOLOGY OPTION

1. Connection to Shore Facility

Given the technology available today, the quickest and most cost effective method of reaching the fleet unit is to connect PHD to a shore facility located in the homeport of the desired unit (See Figure 5-1). This service can be provided and maintained by DISA or by a commercial Internet provider.

The most logical location for the establishment of a "workflow node" would be with the local Squadron (DESRON) or Group Commander (CRUDESGRU or CARGRU). The DESRON (used collectively for both Squadron and Group Commanders), controlling the ships' schedules, could coordinate with the units inport and

Connection to a Shore
Facility

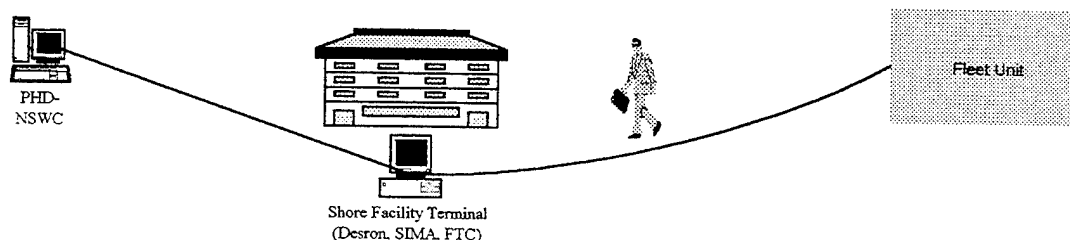


Figure 5-1. Connection to a Shore Facility - Connection to the shore facility allows the controlling agency to find the appropriate unit to assist with the job.

assign a unit and its technicians to support a PHD request upon receipt. The associated costs using this method are relatively low and are further reduced by having only one terminal, or one site license for the software. In addition the costs are even less if the DESRON already has an established DISN or "Internet" connection. The benefit of the DESRON location is that these organizations are in the direct Chain of Command for the fleet units and are better able to assist both PHD and the unit in ensuring the work is completed.

A second choice for the workflow terminal would be the Naval Station's Shore Intermediate Maintenance Activity (SIMA) facility. Here the workflow terminal, or software package running on the SIMA's LAN, could be used by technicians from any of the units inport to support PHD's work request. In addition the local SIMA may have technical expertise on the systems in question and may be able to review the work themselves with the assistance of the units available on the waterfront. This type of approach would allow PHD to construct its workflow without having to worry whether a unit is available or a particular unit is inport.

A third waterfront location to be considered in the establishment of a workflow connection would be the local training command. At many training commands, weapon systems are in place for classroom work and therefore technicians may be available to assist in PHD's efforts, especially those that involve the maintenance or trouble shooting of the system in which these commands specialize their training. This type of location for a connection may be most beneficial for the Aegis units which have established Training Support Groups (ATSG) at Aegis homeports. Regardless of the method used to get to the ship, a connection and the inclusion of the particular system's A and C schools would provide access to the senior fleet technicians with the wealth of knowledge.

a. PROS:

There are many benefits of a waterfront connection of this nature. As mentioned, the DESRON or SIMA can locate a unit to assist with PHD's request based on the unit with the best availability to help, or with the most experienced technicians available. The bandwidth available in a terrestrial based system is currently greater than any "wireless" service can offer. PHD can almost always be assured that the item to be evaluated will be completed since there will be a number of assets the DESRON or SIMA can draw on. Finally, SIMA and DESRONs may have connections to the "Internet" already established and therefore the cost of establishing the connection is greatly reduced.

b. CONS:

The negative aspect of this method is that it does not actually take the workflow to the fleet unit. This method does not terminate at the ship where the technician can take the workflow request directly to his/her system and verify that the information they have been asked to review is accurate or the recommendations are valid. On occasions, traveling to and from the SIMA or DESRON may not be feasible for the type of work being conducted.

2. Connection to Ship Inport

The second option for using a shore based connection for incorporating the fleet unit into PHD's workflow would be to extend the WAN connectivity to the ship inport through the use of a shore based connection (See Figure 5-2). This would include the use of a direct DISN connection to the unit provided through NCTS Pensacola or another DISA agent and through the use of a wireless network such as wireless LAN systems, ARDIS or one of the upcoming CDPD systems. The DISN connection would be established in the same manner as a connection to the unit's DESRON or SIMA.

Wireless connections to ships inport would be able to provide connectivity to the fleet units without the requirement of returning to the same berth each time. The wireless systems also have the benefit of being able to reach the ship while in proximity

Direct Connection to a Ship

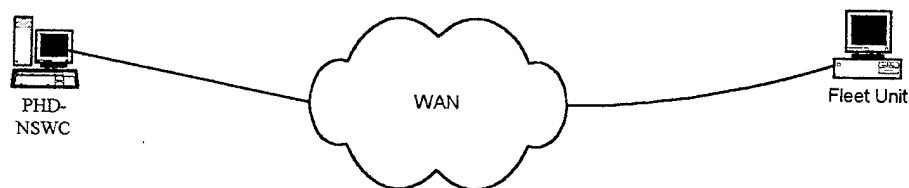


Figure 5-2. Connection to the Ship. - A direct connection to the Ship gives the technician the ability to use his equipment to verify recommended changes.

to shore while underway. These systems would have the same reach as would a cellular phone does at sea today. Also the use of such a system in a battlegroup environment would allow the flagship to transmit to the other units in the battlegroup acting as the base station for the system. Data could then be transferred to the flagship via other methods and then forwarded to the other units via the wireless system.

a. PROS:

Being able to have a connection directly to the ship would be the greatest benefit of the direct connection. Technicians would be able to conduct hands-on work with their equipment and be able to fully assess the proposal that PHD is making.

b. CONS:

On the other hand, a direct connection to the ship with this method would result in only partial connectivity to the unit. During underway periods, PHD would be without the input from the unit thus holding up the workflow progress and defeating the purpose of the system. In addition, the connection may be too expensive to establish for such an operation. Since this would not be the only use for a direct connection of the fleet units to shore, deciding who would pay the bill for such an endeavor would have to be a major question. A third problem with these systems is that when they do not have the hardwire direct connection, the wireless services available today do not have the bandwidth required to send large scale engineering drawings.

B. FUTURE TECHNOLOGY OPTION

As previously noted, wireless connections to ships at sea are the latest area of research for many within the DoD. In general, the deployment of the ATM/SONET network and development of wireless WANs are the two biggest trends in the telecommunications field. Within the next few years there will be a complete revolution in the way communications, both voice and data, will be conducted to and between fleet units. Today however, there are relatively few options for the networking of the fleet unit to PHD's workflow requirements while that unit is underway (See Figure 5-3).

Currently the only regularly used method to transmit data to underway fleet units would be through the use of the SALTS/INMARSAT system. While not providing the complete bandwidth required, it is the only open option available for at sea connectivity. Within the DoD, other programs exist for the transmission of information to ships. However they are for the most part experimental or "stovepipe" and can not be relied upon by PHD for regular use.

The promises of the commercial LEO systems, and the re-action by the traditional GEO providers to provide similar services, should by the turn of the century provide a variety of high-bandwidth systems and services to choose from. If all the systems currently proposed were available today, the recommendation would be to use the Spaceway or Teledesic system. Both services will offer similar features, global high-bandwidth data transmission, and bandwidth on demand up into the gigabits range.

Connection through a Satellite WAN

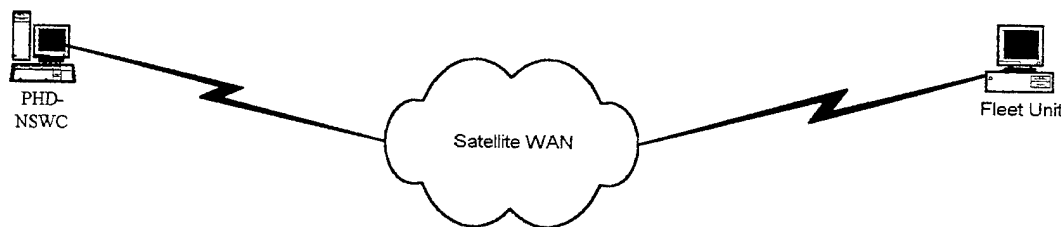


Figure 5-3. Future Technology Option - The development and use of Satellite based WANs will dramatically change the way DoD conducts communications.

However, of the two, Teledesic would provide added benefits due to its small antenna size and low power requirements. Of the many LEO systems under development, it is the only system designed for data communications. Iridium specializing in telephony, does not suit the needs for high-bandwidth data transmissions, and Globalstar, Orbcomm, and Odyssey have the main goal of providing paging, fax, voice and simple messaging services, maintaining a 2400-9600 bps data capability that would not meet PHD's needs.

As far as choosing between the two designated data carriers, as a GEO satellite system, Spaceway requires the use of a directed fixed dish antenna for communications with the satellite. As a LEO satellite system, Teledesic employs an omni-directional antenna with a low power output making it easier to place on a ship and reduces the requirement for transmitter space. However since neither are operational, it is too early to tell which will be successful.

a. Pros:

The benefits of using a LEO or GEO global system would be the seamless integration of the fleet unit into the workflow plans of PHD. Whether at sea or pierside, the workflow information could be sent directly to the unit for rapid evaluation, annotation and return in the minimal amount of time.

b. Cons:

The negative side to the LEO/GEO issue is that neither of these systems are in place, and there is no proof they will be able to deliver what is promised. It is too soon to tell how the use of these systems will be embraced by the personnel in charge of DoN's communication infrastructure. The use of a LEO system will drastically shift the balance in the highly competitive market for DoD's communications needs.

C. CONCLUSION

Connecting the fleet unit to the workflow of PHD-NSWC will only provide benefits to the fleet users and PHD personnel. With the shrinking amount of uniformed personnel from which to draw the end-user perspective, the engineer and logistician at PHD need to rely more heavily on the experience that can only be found on fleet units.

The present methods available for the connecting of the fleet unit to PHD are obviously far from meeting the requirements of providing for a two-way workflow solution. Future methods do hold promise, however, for being able to establish these types of workflows and having the fleet be an active participant in PHD's functionality. LEO systems such as Teledesic, Iridium, and Globalstar and GEO systems such as

Hughes' Spaceway project, along with the advances made by DoD in the area of wireless connectivity provide the promise of being able to communicate seamlessly between fleet and shore and have any type of facility integrated into the work processes.

As the definitions of workflow continue to solidify throughout the information technology community and the concept of workflow continues to take root in the business workplace, the importance of workflow will become evident to the leaders of the military as well as industry. The tools used in the implementation of workflow continue to improve and will include those items that are required to make workflow the value added process that it promises. From use as a management tool to track the workprocess as it is being carried out, to a work productivity enhancement, workflow automation is an advantage for the business and military user. As workflow becomes more and more a part of the norm for organizations, the work of the future can result in an easier and friendlier process. Just ask John and Jane:

"John, we just got word that the ECP on the Evolved Sea Sparrow Missile System has been issued and we need to get it turned around quick."

"I got it this morning, Jane, and have pulled up all the related documents and should have my comments done by tomorrow and then send the package on its way."

"Great, John. Keep up the good work."

Next day...

"Jane, I finished that ESSM ECP and sent it down to engineering, they should have it done in a few days. With their ability to have the ship check out their recommendations, that will eliminate them having to make a trip down to San Diego."

"That's super, John!"

One week later...

"Jane, the ESSM ECP package is complete and I am finishing up on the cover letter with the recommendations. It will be sent off to DC this afternoon."

"That is really great. In the old days, this would have taken us months. Thank goodness for technology."

APPENDIX A. CALS INITIATIVE

A. CALS VISION

The goal of the Continuous Acquisition and Lifecycle Support (CALS) initiative is to enable integration of enterprises on a worldwide basis. The vision is for enterprises (e.g., an original equipment manufacturer and its suppliers, or a consortium of public and private groups and academia) to be able to work from a common digital database, in real time, on the design, development, manufacturing, distribution and servicing of products. The direct benefits would come through substantial reductions in product-to-market time and costs, along with significant enhancements in quality and performance.

To create this networking capability there needs to be developments in both technology and work practices. An "electronic highway" or network is an essential component of this information infrastructure. Basic tenets of the CALS initiative assume an open systems environment, the early adoption of emerging commercial standards, and international coordination on standards for data exchange.

CALS began primarily as a U.S. government and defense industry effort to integrate weapon systems development, production and support. Today CALS has become recognized as an initiative to facilitate the development of a leading edge prototype for "virtual enterprises." As such, CALS has been accepted as the main driver for enterprise integration in nations throughout Europe and the Pacific Rim.

B. HISTORY

CALS began in the mid-1980's as a defense industry initiative to exchange technical data directly with the government in electronic form rather than paper-based documents. Paper-based information is expensive to produce and difficult to maintain. For both industry and government, electronic data would be easier to generate and distribute, require less storage space, and would be faster to update and maintain.

In August of 1988, the Deputy Secretary of Defense directed that the CALS standards be used in the development of certain weapon systems. The use of CALS

standards would enable not only better management of technical data but also overall improvement in productivity and quality through the sharing and integration of data among government agencies and contractors. The significance of these benefits was recognized by government and industry alike, and today the CALS strategy is being adopted by organizations around the world.

The CALS acronym has evolved over time. In 1985, CALS began as Computer Aided Logistic Support. It was defined as a strategy for transitioning from paper-based weapon system acquisition and support processes to an integrated and automated environment. As the strategy evolved, in 1988, the name expanded to include acquisition, becoming Computer-aided Acquisition and Logistic Support. In 1993, the definition of the acronym was changed again to Continuous Acquisition and Lifecycle support. This most recent change was meant to reflect that CALS is really about information and process improvement, and that both are continuous. This latest focus recognizes CALS as a facilitator for world wide process improvement and enterprise integration.

C. CALS INITIATIVE IMPLEMENTATION

The implementation of the CALS initiative can be broken down into five primary areas: technology development and demonstration, acquisition process, technology infrastructure, standards, and training and outreach.

Technology development and demonstration addresses the development and demonstration of technologies that can support the integration, management, and secure electronic interaction of large volumes of digitized data. The acquisition process area addresses the implementation policy and procedures, program management guidance and other contractual processes for major system acquisitions. The method in which industry and government receive, store and transmit data is addressed by the primary area of technology infrastructure. Standards addresses how the CALS initiative integrates selected, existing international and national standards, and training and outreach aims at

the information dissemination process for effective cultural change needed to implement the CALS initiative throughout the government and industry.

Of the primary areas discussed above, the area of technology infrastructure is one of the most challenging. The modernization of DoD and industry infrastructure and redesign of business and technical processes is required to receive, integrate, access and use data effectively in major systems and subsystems life cycles. Some of the current ongoing work in the area of technology infrastructure includes an integrated database, an enterprise integration model, the JCALS program, the JEDMICS program, EC/EDI, and FCIM.

The integrated database, dubbed as the Integrated Weapon System Database (IWSDB), will be a collection of shared product definition, management, and support data used throughout the lifecycle of a major system. Although the structure of this database is still evolving, the intent is to have this database become an integrated, shared data environment that will enable an authorized user to access information regardless of geographic location.

The enterprise integration model will assist managers in planning the activities and mapping the data needed to accomplish the defense mission such as acquiring assets. The CALS initiative will play a vital role in the expansion of the model's framework to incorporate and create the bridge between DoD and industry and national and international participants.

The DoD Joint Computer-aided Acquisition and Logistic Support (JCALS) program will support the IWSDB and network structure. JCALS is the baseline for the DoD CALS digital infrastructure and as such will be discussed in more detail below.

The DoD Joint Engineering Data Management Information and Control System (JEDMICS) program is an initiative to acquire, store, manage and distribute engineering drawings and related data in digital form. JEDMICS serves as the joint services engineering drawing repository and interfaces with JCALS.

Electronic Commerce/Electronic Data Interchange (EC/EDI) is the digital exchange of information needed to conduct business. The goal is to provide the government and industry with the capability to initiate, conduct and maintain business relations without requiring the use of hard copy.

Flexible Computer Integrated Manufacturing (FCIM) is the integration of equipment, software, communication, personnel and business practices within an enterprise to rapidly manufacture, repair and deliver items on demand with continuous improvements to the process. FCIM applies to the full circle of the enterprise from point of product need identification to delivery to the customer.

D. JCALS: AN OVERVIEW

The premier implementation of the CALS initiative, as of this time, is the Joint Computer-aided Acquisition and Logistics Support (JCALS). JCALS is an outgrowth of the US Army's Technical Information Management System which in March of 1987 grew into Army CALS (ACALS). In May 1988, the Office of the Secretary of Defense approved an acquisition strategy for ACALS and released the Request for Proposal (RFP) in June 1988. Originally four contractors were awarded the ACALS contract in August 1989. In January 1991, the Army was directed to include joint requirements and provide the design, development, acquisition, and implementation options for a joint program. ACALS was established as a joint services program, JCALS, in October of 1991 and the JCALS contract was awarded to Computer Sciences Corporation (CSC) in December 1991.

JCALS was initiated as a result of the joint services' goals to digitize technical and logistic support information in existing systems, and reduce development, acquisition, and support costs associated with weapons systems. JCALS is an evolutionary program to modernize the processes of capture, management, interchange, and processing acquisition of logistic and technical information. The following are the overall objectives of the JCALS program:

- Develop and implement a systems architecture to provide for the dissemination of weapons system technical information from existing systems into a common infrastructure that is accessible to all JCALS users.
- Develop and implement a common integrated logistic technical support database concept and structure. Such a database concept and structure will be used to support the system throughout its life cycle.
- Identify and implement Government and industry interfaces to enhance the exchange of technical information.

The JCALS solution is a distributed open system employing a 100 Mbps FDDI (Fiber Distributed Data Interface) in a client-server, multi-level secure (B1, future B3) architecture. JCALS supports both GOSIP and TCP/IP functionality in a shared data environment including both government and contractor sites. It is an integrated suite of software tools operating in a UNIX/POSIX environment that provides the capability to improve existing processes. (See Figure A-1.) The software suite includes office

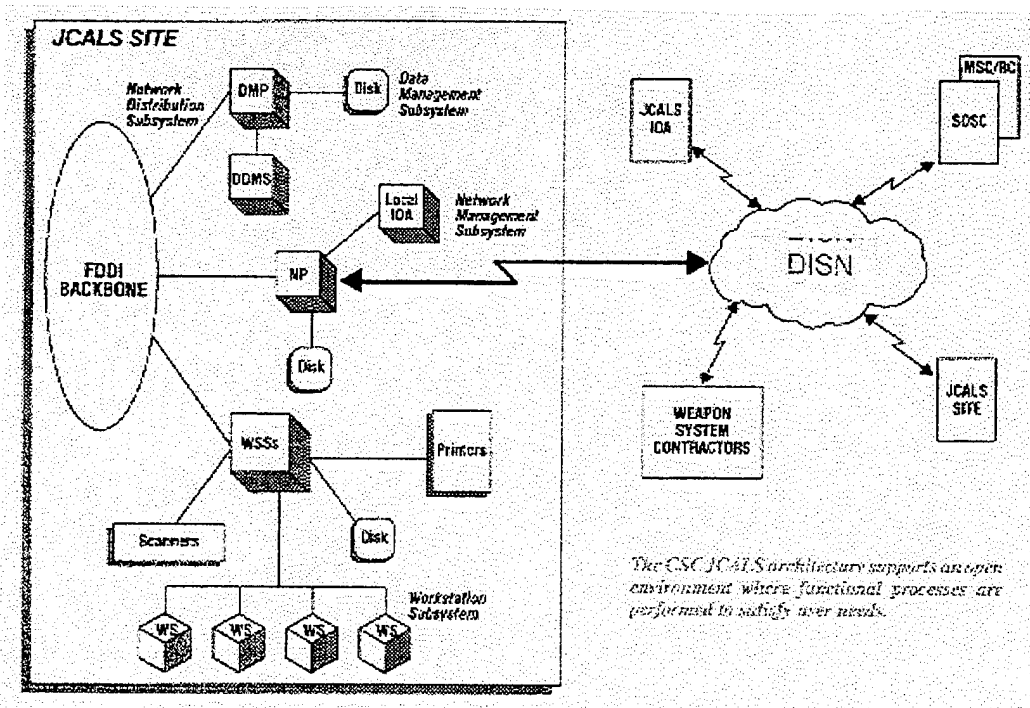


Figure A-1. The JCALS Architecture - a distributed open system in a client server, multi-level secure environment (CSC, 1994).

automation (word processing, spreadsheet, and graphics), ILS/RAM tools, authoring/electronic publishing, reference library, automated logistics functions, CAD/CAM/CAE capabilities, document image processing, configuration management services, coordination and approval services, and workflow management. Besides the above software tools, it has system-wide network management and control from any JCALS site and provides support for workstations ranging from PC's to high performance CAD/CAM systems.

Some of the unique features of the JCALS systems include the workflow manager toolset, which provides the capability to create and monitor jobs at any CALS site and provides a common work environment for all JCALS users and access to all CALS workbench tools and applications. JCALS is a standards-based system that reduces the risk of technological obsolescence and provides a foundation on which technological enhancements can be made. Finally, it is the only commercially available, POSIX-compliant UNIX-based multilevel secure operating system.

APPENDIX B. SPACEWAY

A. REVOLUTION IN COMMUNICATIONS

Spaceway is a wireless expressway that will provide businesses and consumers around the world with affordable access to a variety of interactive, high-speed and high-quality broadband telecommunications services. Spaceway utilizes a global system of geostationary satellites that will allow users to transmit and receive voice, video, audio, and data hundreds of times faster than conventional telephone lines. Access to the system is easy and instantaneous through use of a low-cost (\$1,000), two-way 26-inch antenna. Spaceway will offer business users a wide variety of applications, including desktop video telephony and conferencing, computer networking, technical tele-imaging, CAD/CAM transmission and high-speed, low-cost access to the next generation of on-line multimedia data bases at rates from 16 Kbps to 2 Mbps and higher, if desired.

The Spaceway System will play two key roles when service begins in 1998. The first is infrastructure enhancement: to provide basic telephony to underserved areas of the world, and to allow these areas regional and global telecom access. The second is interactive multimedia: to provide advanced communications to the global marketplace, where huge quantities of information must be accessed and shared electronically.

B. REGIONAL FOCUS: WORLDWIDE CONNECTIVITY

Spaceway is a Fixed Satellite System (FSS) using spacecraft in geostationary earth orbit (GEO). Operating in the Ka-band spectrum, Spaceway will consist of four interconnected regional satellite systems providing service to nearly all of the world's population. The first regional system will offer service in 1998, with the other three regions going on-line by the year 2000. Spaceway provides bandwidth on demand - the ability to transmit and receive voice, video, audio, and data at any time from any place - at up to two megabits per second. It seamlessly integrates into the terrestrial infrastructure, enabling Spaceway customers to communicate with anyone served by the terrestrial network.

C. A WIDE RANGE OF AFFORDABLE APPLICATIONS

1. Infrastructure Enhancement

In most developing countries, making basic telephony available to all citizens is a national priority. However, even the most advanced terrestrial system is challenged to provide service in regions with low population density, poor economies, or difficult topography. Spaceway technology can readily overcome these constraints. The system offers telephone and facsimile services that can significantly extend the telecommunications infrastructure in developing countries.

a. Universal Access.

The system provides a cost-effective means to achieve universal service, especially in rural and remote regions. An example of how a region with poor or non-existent telecommunications infrastructure would be served by the system is the Spaceway Telecommunications Center (STC). By placing an STC in a town or village, individuals can immediately make or receive voice, video, data and fax transmissions to and from anywhere in the world.

b. Affordable Telephony.

Spaceway provides affordable telephony and data communications to assist economic and industrial development. Unlike mobile telephony systems, Spaceway uses long-life, high-capacity geostationary satellites that focus all communication beams on populated regions. This approach will offer the most efficient, low-cost service, competitively priced with domestic and international terrestrial networks. As well, the cost per voice circuit for the Spaceway System will be 10 to 20 times lower than proposed mobile systems.

c. High Quality Telephony.

The system's all digital 16 Kbps voice channels incorporate echo cancellation to ensure excellent voice quality—noticeably better than the mobile

alternative at 5 Kbps.

d. Rapid Deployment.

Because the system is satellite-based, it can deliver rapid infrastructure deployment regardless of population density, economic conditions or difficult topography.

e. New Generation of VSATs

Improved functionality and lower capital and operating costs will enable more businesses to electronically connect multiple locations for transactions such as retail point-of-sale and inventory control.

2. Interactive Multimedia

Spaceway offers broadband services for a variety of consumer and business applications for those who have emerging needs for advanced services, but have no access to terrestrial high data-rate lines.

a. Computer Networking.

Organizations can unite operations at multiple locations by joining their remote LANs into a single high-speed network through Spaceway.

b. Tele-Imaging

Physicians can use the system to transmit high-resolution images (X-rays), allowing specialists to interact with patients at distant locations (see Figure B-1).

c. Interactive Distance Learning.

Users can establish low-cost, two-way education and training programs that bring together students at multiple sites and instructors who are miles away.

d. Digital Libraries.

Spaceway provides rapid access to on-line multimedia information.

e. Telecommuting.

The system's high-speed, interactive data transfer capacity makes rapid

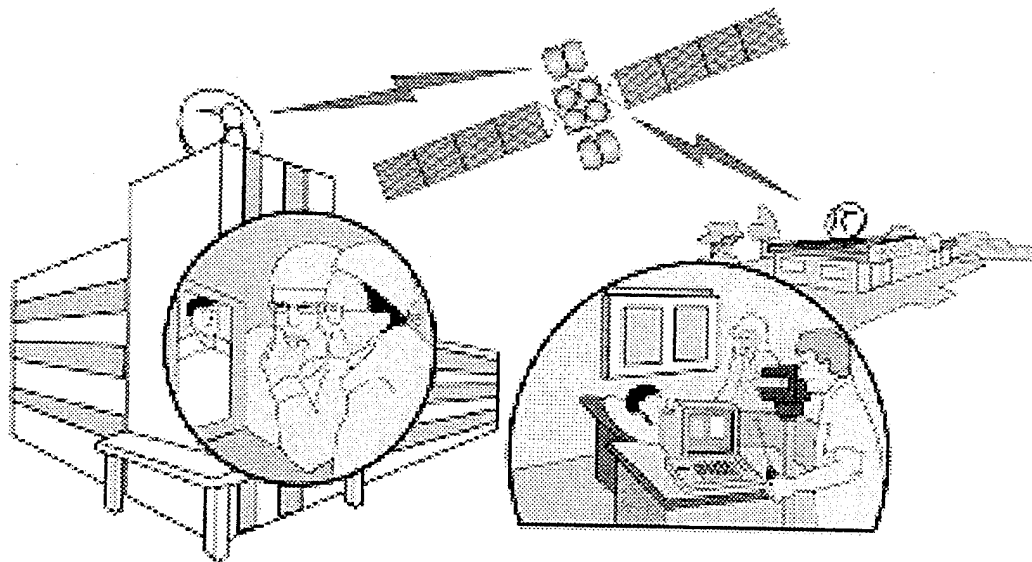


Figure B-1. Tele-imaging - High-bandwidth data capacity makes demanding applications such a tele-medicine a reality (HCI, 1994).

intellectual exchange between office and home effective and easy.

f. Videoconferencing.

Spaceway delivers high-speed ISDN-type communications for desktop videoconferencing between office locations.

D. EASY ACCESS: SEAMLESS CONNECTIVITY

Spaceway end-users will access the system with an inexpensive Ultra Small Aperture Terminal (USAT), utilizing a 26-inch diameter dish or antenna. Costing less than \$1,000, this terminal is easy to install and will be available through commercial outlets and consumer electronics retailers. USATs incorporate complete digital electronics that can interface with a wide variety of end-user equipment such as telephone, facsimile, personal computer and video. The system is fully compatible with a

wide range of terrestrial transmission standards such as ATM, ISDN, Frame Relay and X.25. The Spaceway USAT represents the next generation in satellite communications technology and provides bandwidth on-demand, hubless full-mesh networking, a wide range of data rates and full terrestrial compatibility.

E. HUNDREDS OF TIMES FASTER

Spaceway transmits and receives hundreds of times faster than conventional telephone lines. An optional broadband uplink terminal will support applications requiring up to 20 megabits per second. (Hughes Communications Inc., 1994)

<u>Application</u>	<u>Information Content</u>	<u>Phone Line (9.6 Kbps)</u>	<u>Spaceway 384 Kbps</u>	<u>Spaceway 1.5 Mbps</u>
Digitized Photo	1 Megabit	2.5 Minutes	2.6 Seconds	0.7 Seconds
CAD/CAM	2 Megabits	5.0 Minutes	5.2 Seconds	1.4 Seconds
X-Ray	12 Megabits	21.0 Minutes	31.3 Seconds	7.8 Seconds
Digital Library	Washington Post Sunday Edition	28 Minutes	41.6 Seconds	10.4 Seconds

Table B-1. Comparison of download times for various applications.

APPENDIX C. GLOBALSTAR

A. GLOBALSTAR SYSTEM OVERVIEW

1. General

Globalstar has developed a unique global satellite system that addresses the growth in demand for telecommunications services while providing coverage that a cellular telephone system cannot economically match. The Globalstar system introduces the ability for anyone, anywhere, at any time, to communicate via voice, data, or facsimile transmissions.

Globalstar is a low Earth orbit (LEO) satellite-based mobile communications system that is interoperable with current, and future, terrestrial mobile and switched telephone networks of all types.

The Globalstar system is designed to provide low-cost personal communications to the everyday user, while providing maximum revenue to the service provider.

Globalstar fulfills current unmet telecommunications needs by providing an inexpensive way for mobile service providers to increase their coverage area and to add new customers in areas where it is not economical to provide terrestrial services. As a non-bypass network, the system enhances rather than competes with existing local, long-distance, private and specialized telecommunications networks.

Globalstar offers worldwide mobile voice and data, paging and messaging, and radio determination satellite services (RDSS) to and from efficient hand-held and vehicle mounted transceiver terminals, regardless of location. Globalstar's terminals, hand-held units in particular, are small, state-of-the-art designs, operated in the same manner that a user would operate today's wireless cellular telephones. The system's mobile terminals are equipped with omnidirectional antennas, eliminating the need to be pointed at a satellite to achieve and maintain reliable linkage.

2. System Concept

The Globalstar system is composed of 48 LEO satellites circling the globe, operating through gateways in conjunction with existing terrestrial networks. All calls are set up and processed on the ground by the local gateway terminal. Gateway equipment consists of hardware, software and a packet switched data network for operational control, roaming access and other administrative functions. Gateway stations provide interconnections to public switched telephone networks (PSTN).

Since Globalstar's orbiting satellites are in continuous motion relative to the gateways, the gateway antennas are used to track the satellites.

Code division Multiple access (CDMA) technology, coupled with the omnidirectional antennas of the mobile users, is used for both the user-to-satellite link and the satellite-to-user link. This allows users to connect with multiple satellites while increasing reliability, decreasing blockage and reducing link margin requirements.

Periodically, it is necessary to hand off communication transmissions from one satellite to another due to the continual orbit of the satellites and changing areas of coverage. The Globalstar system employs a patented soft hand-off technique, developed by QUALCOMM, to accomplish this satellite-to-satellite exchange.

As the active satellite moves out of range, the system automatically selects and combines the best signal paths from two or more satellites, resulting in improved signal strength and quality. Hand-off occurs only when the new satellite is firmly established in the new coverage area, thus ensuring communications integrity. Hand-off is transparent to both the Globalstar and PSTN users involved, as conclusively demonstrated in CDMA digital cellular field trials by QUALCOMM and other industry leaders.

Globalstar users can select either single- or dual-mode telephone service. A single-mode phone only provides access to the Globalstar system, while dual-mode provides full access to both terrestrial networks and the Globalstar satellite system. A unique serial number designator is incorporated in every Globalstar terminal. The serial number is like a telephone number, but independent of location. This number, along with

an innovative database management program that authenticates the caller ID, will ensure access authorization, prevent fraudulent use and maintain system security. Additionally since the system employs CDMA technology, an inherently private transmission technique, communications privacy is ensured. Figure C-1 shows the Globalstar system concept.

3. System Advantages

Primary advantages of the Globalstar system are its interoperability with and ability to provide low-cost expansion of cellular and other mobile telephone systems. While it is similar to cordless telephones that are installed in many homes, it provides

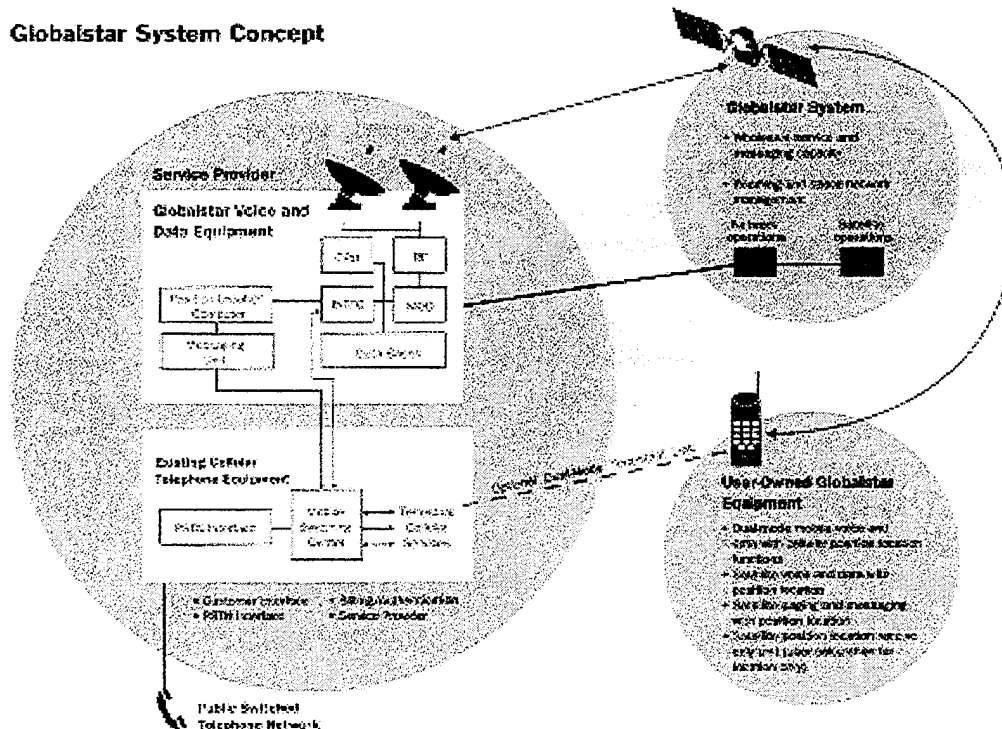


Figure C-1. Globalstar System Concept - Users will connect to the existing public switched telephone network via the Globalstar network or existing cellular telephone systems (Globalstar, 1994).

greater flexibility and unlimited range.

The same Globalstar handset can be used in an office, in a vehicle, in a hotel or while in a meeting anywhere in the world using an individual's own personal subscriber number.

The Globalstar space segment serves government, private networks and telephone systems alike by exchanging data base information and allowing for internetwork connections. Globalstar services are easily added to a terrestrial system. For example, in a cellular-type system, Globalstar emulates a base station input to the cellular switch. All signaling and protocols for establishing and tearing down the call and appropriate billing information are retained. The traffic on the cellular terrestrial system is unimpaired and undiminished by the addition of the Globalstar equipment since transmissions to and from the satellites are carried over different frequencies than those used by the terrestrial system. Globalstar's LEO satellites provide significant benefits for establishing and maintaining continuous, high-quality service to untethered users by avoiding signal delays that occur with medium orbit and geosynchronous satellites.

The number of satellites in the system's constellation is inherently robust. It can even accommodate multiple satellite failures with minimum impact on service continuity because each user on the Earth's surface is in range of two or more satellites.

4. Benefits and Services

Globalstar telecommunications services provide individuals and families with a low-cost, dedicated service access to telecommunications networks principally dominated today by businesses and professionals.

To achieve low cost, Globalstar is structured as an extension and enhancement to existing networks. It will operate on a non-common carrier basis, sharing its revenues with these networks. Globalstar will sell its communications capacity in call minutes, either in bulk or on demand, to the networks. Globalstar services are routed and billed through existing carriers. The carriers may choose to have capacity only or to own a portion of the system and thereby share in the Globalstar profits.

Low-cost users' terminals are the result of using a constellation of LEO satellites. Low and judiciously selected orbit paths minimize the radio frequency (RF) power necessary to transmit information in either direction (user-to-satellite or satellite-to-user). Low cost is also the result of being able to use omnidirectional antennas, CDMA techniques and the latest very large scale integration (VLSI) devices. A mass production approach for the satellites, ground stations and hand-held terminals helps to ensure that Globalstar has the lowest cost implementation possible .

The versatile Globalstar system offers many benefits and services to the users. Examples include:

- Persons living or traveling in areas without cellular service will be able to communicate with people all over the world.
- Businesses with worldwide concerns will have fast, efficient communications among all locations.
- Individuals traveling for business or pleasure will have a ready means to contact office or home, regardless of location.
- Individuals and government agencies will be provided with improved search and rescue capabilities when using the system's location determination and message or voice services.
- Persons stranded by disabled crafts and vehicles will be able to readily call for help and provide their locations.
- Communications between government agencies will improve with the ability to operate from multiple databases .
- Transportation organizations will have an improved means of communication between drivers and operation centers.
- Railroad lines not covered by traffic control systems will have a way to control trains to improve safety and security.
- Handicapped persons, even when confined to wheelchairs, will have a ready, simple-to-use way to request assistance.
- An alternate, or back-up capability, to ground-based emergency alerting and locating services for aviation and marine navigation will be provided .
- Worldwide service connectivity, including operating from aircraft and continuous tracking of valuable cargoes, will be available.
- The system will provide immediate reporting and request for assistance capabilities in natural disasters, accidents and other emergencies.
- Residents of rural or remote geographical areas will have telecommunications service or enhanced capabilities to existing services.
- Emerging nations will have a low-cost communications expansion path.

In summary, staying in touch could mean the difference between winning and

losing a business contract, calling for assistance in an emergency, or having the assurance of your family's safety.

B. GLOBALSTAR SYSTEM DESCRIPTION

1. General

The system uses the latest developments in satellite technology and cellular telephone technology, including the commercial application of CDMA techniques. Globalstar will deploy a constellation of 48 LEO satellites to provide continuous coverage of the globe. Each satellite operates as a simple frequency translating repeater in space, eliminating complex call setup procedures and on-board processing.

The system is configured such that a mobile user is linked to a terrestrial gateway directly through individual satellites, eliminating the need for satellite traffic signal crosslinks. Each satellite will have six spot beams to form coverage regions on the Earth for links between mobile users and the satellites. Each satellite has the capacity for a minimum of 2800 duplex voice or data circuits. Orbit selection and the use of CDMA spread spectrum technology increases the number of circuits over a region with multiple satellite coverage. A large number of users can receive service simultaneously all over the world.

The frequency bands that can be used readily by Globalstar are:

- Satellite-to-user: S-band
- User-to-satellite: L-band
- Satellite-to-gateway: C-band
- Gateway-to-satellite: C-band

Use of these bands will provide a technically reliable service at the lowest possible cost to users. Because Globalstar is a global system, its spectrum allocation is anticipated to be co-primary, and/or if secondary, coordinated with other satellite or terrestrial services.

2. System Elements

The Globalstar system consists of three major segments: space, ground, and mobile user. Figure C-2 shows the Globalstar system architecture. The space segment

Globalstar System Architecture

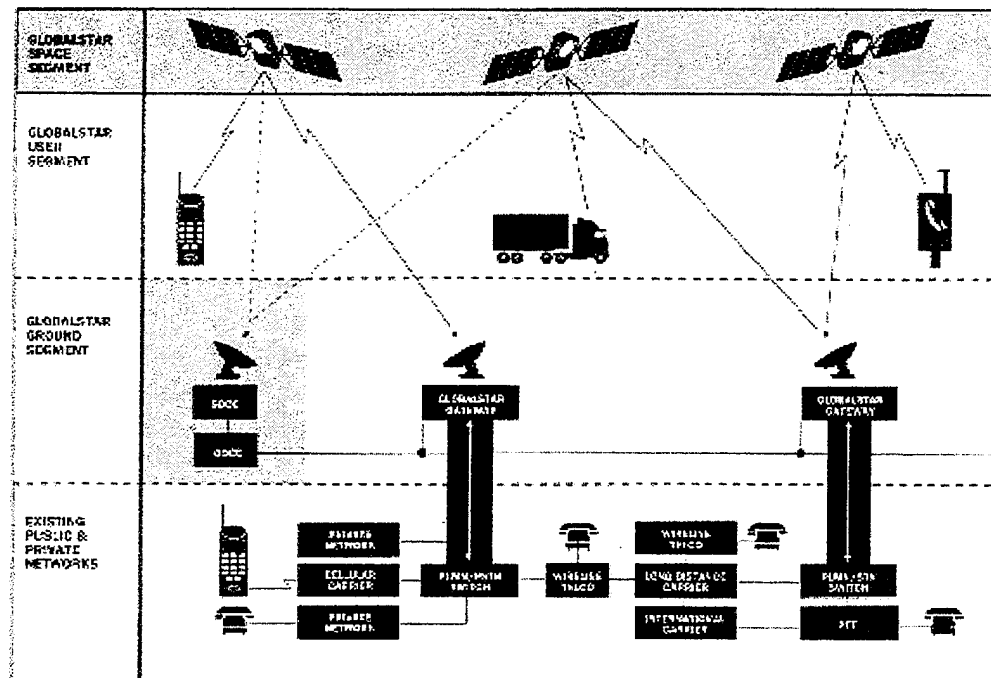


Figure C-2. Globalstar System Architecture - The Globalstar system consists three major segments: Space, Ground and Mobile-user (Globalstar, 1994).

comprises the constellation 48 satellites. The ground segment consists of gateway stations; the telemetry, tracking, and command (TT&C) stations; the satellite operation control center (SOCC); and the ground operations control center (GOCC).

The user segment will initially include several different types of user terminals: a vehicle-mounted unit, a hand-held unit and fixed terrestrial units. Many other options can also be provided to Globalstar users for various services. All segments are designed with maximum system flexibility:

- Efficient use of spectrum with minimum coordination among system operators.
- Compatibility with various cellular systems e.g., Group Special Mobile (GSM) and Advanced Mobile Phone Service (AMPS).
- Manufacturing producibility for economical satellites and launch by various launch vehicles.

- State-of-the-art technology to allow for system improvement to increase system capacity and services.
- Low power, hand-held units for longer battery life and safe operations.

a. Space Segment

The space segment consists of a Globalstar constellation of 48 LEO satellites in circular orbits with 763 nautical miles (1400 km) altitude (see Figure C-3). Serving a worldwide market, these satellites will be launched into 8 orbital planes, with 6 satellites equally phased within each orbital plane, to provide continuous, uninterrupted global coverage. Each orbital plane has an inclination angle of 52 degrees. Each satellite



Figure C-3. Globalstar System Satellite Constellation - Orbit parameters: 763 nautical miles x 52 degree inclination. Eight orbital planes with six satellites each (Globalstar, 1994).

has a 7.5 degree phase shift to the satellite in the adjacent orbital plane. Over the United States, coverage is such that there are 5 or more satellites providing Globalstar services for 100 percent of the time. This ability to provide global coverage, in comparison to a geosynchronous satellite's partial coverage, makes it possible to amortize the cost of the constellation over the world market. Low orbit also decreases the required satellite RF power level by at least 100 times and reduces signal Data delay. Low delay eliminates echo, a condition that is prevalent with geosynchronous systems.

The six spot beams of the satellite generate elliptical coverage cells on the surface of the Earth. The major axis of these elliptical coverage cells are aligned with the velocity vector of the satellite movement. Therefore, the time a user stays within the same satellite beam "cell" is increased and the number of call hand-off operations among the satellite beam "cells" is reduced. The Globalstar satellites' spot beam antennas are also designed to compensate for the difference in the satellite-to-user link losses between the "near" and the "far" users, so that the power flux density of the "far" users is the same as the "near" users. This Globalstar antenna design will eliminate the "near/far" problem experienced by many cellular-type systems.

b. Ground Segment

The Globalstar ground segment consists of gateway stations, the GOCC, the TT&C stations and SOCCs.

(1) Gateway Stations - Each satellite communicates with the mobile user via satellite-user links and with gateway stations directly via feeder links. The RDSS functions are performed at the gateway stations or at the user terminal while voice/data communications are routed through the gateway stations. Each gateway station will communicate with three satellites simultaneously. The gateway station handles the interface between the Globalstar network and the PSTN/Public Land Mobile Network (PLMN) systems. This equipment will be supplied by gateway owners/service providers. There are many gateway stations distributed throughout the world. Eight gateways provide double coverage to all users in the continental United States. Ideally, a gateway

may be provided for each cellular telephone operator. Most of these gateway stations are connected directly to the mobile switch centers of the PLMN. For Globalstar service, gateway stations and other NCCs will be installed all over the world by Postal, Telephone and Telegraph (PTT) organizations or communications carriers of different countries to provide interconnection to their local PSTN/PLMN. Gateways will be configured to match the capacity requirements of given service zones to minimize costs. A particular influence is the scope of existing PSTNs. Each country can independently have its own gateway(s) and have complete control of system access by users within its own boundaries. The system includes instant position location capabilities to establish user location for each call, either inbound or outbound. There is no limit to the number of gateways that can provide service in an area; gateways may overlap coverage areas without limit.

(2) Ground Operations Control Center - The GOCC provides the capability to manage the Globalstar communications networks. Its functions include registration, verification, billing, network database distribution, network resources allocation (channels, bandwidth, satellites, etc.) and other network management functions. Other Globalstar services, such as message service, can also be provided through the GOCC. Initially, there will be one GOCC for cellular like systems in the United States. GOCCs can be added later, as needed. Additional GOCCs will be established for international Globalstar or private networks.

(3) Constellation Control - The Constellation control operation includes the TT&C station and the SOCC. The TT&C stations monitor each satellite's operation by the telemetry of the satellites and send commands to the satellite to control its own orbit performance. The TT&C stations also perform tracking and ranging functions for the orbiting satellites. The ephemerides of the satellites' positions are computed at the SOCC and distributed to all GOCCs. The SOCC processes the satellites' orbit information for various network functions. The processed information and data bases are distributed via the GOCCs to Globalstar gateways for tracking and other

purposes. The SOCC also plans and executes orbit station-keeping for the satellites so that all satellites are maintained in the appropriate orbits. The Constellation Control Operation supports the launch operation and in-orbit test operation.

c. User Segment

During the initial phase of the Globalstar network, there will be two kinds of user equipment. These will be based on unobtrusive, small, omnidirectional antennas and include hand-held terminal units for voice and RDSS service and vehicle-mounted and fixed units for RDSS only terminals. As the market demand rises, other user equipment, providing various Globalstar RDSS, voice, and data services, will also be introduced.

On an option basis, terminal service can be either single or dual mode. The single-mode terminal is solely for access to the Globalstar system, while the dual-mode terminal can be used with the Globalstar system and terrestrial cellular telephones or other mobile radio facilities.

Hand-held unit RF energy densities will be below the stringent biological microwave radiation hazard limits set by governments to protect users from microwave heating. Average transmit power at the terminal is less.

3. Services

a. Wireless Mobile Voice and Data

The Globalstar system provides voice and data services in conjunction with terrestrial cellular telephone service providers and/or other communications service providers. The Globalstar system covers the following four main groups of users:

- Mobile users working in and/or resident in areas without terrestrial mobile coverage
- Mobile users working in and/or resident in areas with terrestrial mobile coverage, but roaming into areas without terrestrial mobile coverage
- Fixed users working in and/or resident in areas without fixed telecommunications service.
- Private or specialized network operators.

Users groups might include government agencies, commercial users, fleet

managers, land and water vehicles, persons traveling on business or for pleasure, emergency service providers, transportation entities and others.

Government agencies will benefit from two-way voice communications and position location capabilities in the areas of disaster relief, law enforcement, air traffic control, resource management and weather reporting.

Commercial users that might use the Globalstar system include rural facilities that are not served by a PSTN or cellular network, utilities that require regular but infrequent monitoring of their assets (e.g., meter reading), security services (tracking of stolen property), and resource management systems (remote periodic monitoring of environmental variables).

The management of vehicle fleets requires extensive location and communication services. Fleet management users include interstate trucking, passenger buses, rail freight and inland waterway users.

In addition, travel services provide a natural market for Globalstar service, including global paging, recreational activities, public communication, shipping, general aviation and emergency services.

b. Wireless Mobile RDSS

The Globalstar system provides RDSS on a stand-alone basis or in combination with messaging and voice communication services. By subscribing to these services in various combinations, users can meet their location determination and communications needs at costs equal to or lower than comparable terrestrial facilities.

The most basic RDSS service the Globalstar system provides is the passive position location service, in which the user's position is computed by the user. This service is based on a pilot tone that is transmitted by the Globalstar system. Applications for this service include recreational activities such as backpacking or boating. This service will be provided without additional charge to users with transceivers.

A second RDSS service the Globalstar system provides is RDSS with

two-way messaging. In this case, the user can request that his position be computed by the gateway and communicated to him or to others, such as a hospital or home. This service can be used in the case of emergency, when the user wants to communicate a situation (e.g., medical emergency or disabled vehicle) to rescue service providers or family.

A third RDSS service the Globalstar system provides is RDSS with position computed by the gateway and communicated to selected subscribers. Applications for this service include location of fleet vehicles, tracking of hazardous waste shipments, tracking of military movements, or location of stolen vehicles. Combining the Globalstar system and the PSTN, RDSS coverage for this service extends throughout the world.

4. Network Architecture

The Globalstar network architecture has been designed to support many quality voice and data services in an efficient manner. Although all gateway stations will link users to existing networks, some Network Coordination Gateways (NCGs) will perform the more complex functions of the operations center of a Globalstar service provider. An NCG will have additional equipment to perform resource assignment, network timing and coordination, and communications load monitoring. All of a service provider's standard gateways will interface with the NCG through a packet switched data network. For smaller operations, the NCG will be the operator's only gateway.

a. Voice Service Protocols

(1) Mobile-Initiated Inbound Calls - All calls initiated by mobile users are first processed by the NCG. After a short synchronization sequence, billing verification, and location data base interrogation, the NCG sends information to the assigned gateway about the resources that have to be used (code, channel number and sync information). Next, the NCG transmits traffic channel assignment information to the mobile user through the signaling channel that is paired with the one the mobile is listening to. Once the mobile is synchronized to the traffic channel, the call setup is

complete.

(2) PSTN Calls to Mobile Users - The protocol for call setup is similar to that for outbound transmission. First, when making a local call, the PSTN user dial-up of a mobile user rings the cellular mobile switch. This switch identifies that the call is to a Globalstar user and establishes that the user is in the satellite cell through a data base accessed via signaling exchange on a packet data network. When it is determined that the user is authorized to receive the call, the assignment is given to the gateway which pages (rings) the mobile for transmission synchronization. Thereafter, the mobile switches to the assigned traffic channel and communications begin.

(3) Mobile-to-Mobile Communications - Communications occur through the two local gateways of each mobile. The same gateway may process a mobile-to-mobile call.

b. Data Service Protocols

A variety of data service protocols are compatible with the Globalstar system transmission scheme. In all cases, synchronization, resource assignment procedures, authentication and billing procedures will be achieved as in the voice service case. There are some differences in the sharing scheme of the traffic channel, e.g., for low-rate messaging service.

c. RDSS Protocols

The Globalstar system will base its RDSS service on a derivative of the OmniTRACS system positioning technique, a proven technique that is directly applicable. The Globalstar system will have two modes of RDSS service. The primary mode consists of active participation of the terminal with the gateway, where the gateway computes the position of the user terminal. A second mode allows the user to passively acquire the satellite downlinks and derive its position with available observables, such as range and doppler; this does not require active dialog with the gateway.

5. Billing

Billing will be based on circuit time usage and type of service. Voice calls are charged from answer until circuit release. Data service charges are based on the amount of bits transmitted, which is equivalent to the amount of time network interfaces are used. RDSS service charge depends on the mode. For calculations at the user terminal access is free, except for the monthly user subscription charge. For two-way RDSS, the charge will be based on the number of location calculations performed and transmitted.

6. System Expansion

The system has enough flexibility and expansion capability to meet ever increasing domestic and worldwide demand. The satellites are designed to have a 7.5 year mean life. Using a simple satellite design and overlapping coverage, continuous and reliable service will be provided to Globalstar system customers throughout the life of the first generation system.

Additional satellites can be launched to provide greater satellite coverage over all areas. The Globalstar system's use of CDMA allows the capacity in areas covered by two or more satellites to increase significantly. Increasing the number of satellites within range of a mobile terminal doubles the satellite power flux density which nearly doubles the capacity in the area of two-satellite coverage.

Another way in which double coverage can increase capacity is through the use of diversity. When a call's signals are transmitted through two satellites providing coverage of a mobile terminal's region, CDMA technology allows the mobile terminal to receive both signals and perform coherent diversity, combining two sets of signals. This provides path diversity. Path diversity will increase user call reliability and permit the link margin to be reduced, thereby lowering the mobile terminal's use of available downlink power. This same signal processing will prevent call drop-off when link blockage occurs (due to trees, buildings, etc.) to one of the satellites in view. (Globalstar Inc., 1994)

APPENDIX D. TELEDASIC

A. TELEDASIC SYSTEM OVERVIEW

Teledesic Corporation ("Teledesic") is seeking FCC license to construct a global network of low-Earth orbit satellites that will help deliver a wide array of affordable, yet advanced, interactive broadband information services to people in rural and remote parts of the United States and the world. The company seeks to forge a global partnership of service providers, manufacturers, governments, and international agencies to help bring the information revolution to people who could not be served economically through existing technologies.

The benefits to be derived from such services are as vast as the areas of need to which they can extend. With universal access to interactive broadband capabilities, information can flow freely between people, creating wider communities of interest and support. In the field of health care, for example, doctors and other caregivers can consult with specialists thousands of miles away, share medical records and X-rays, relay critical medical information during epidemics, distribute globally the latest medical research, ensure priority routing of medical supplies during disaster relief programs, and provide remote instruction in nutrition, sanitation, and prenatal and infant care.

The interactive broadband capabilities of the Teledesic Network, coupled with its wireless access technology, also hold the promise of delivering distance learning services to the most remote parts of the United States and the world, thereby offering meaningful educational opportunities to people who would otherwise be cut off, either economically or geographically, from traditional centers of learning.

Advanced technologies have revolutionized the way people exchange and process information in urban areas of the United States and other developed nations. But there is a broader, unmet need. Today, the cost to bring modern communications to poor and remote areas is so high that many of the world's people cannot participate in the global community. Yet the benefits of the communications revolution should be extended to all

of the world's citizens, including those who do not reside in or near centers of commerce or industry, who do not have ready access to doctors, hospitals, schools, or libraries, and who are at risk of being shunted aside. Teledesic hopes to inspire an effort to serve these people.

The pressing need to bring advanced communications technology to developing nations and remote regions of industrialized nations was acknowledged in the Federal Communications Commission's decision to establish a narrowband, nonvoice, non-geostationary mobile-satellite service and to award a pioneer's preference for a license in the service to Volunteers in Technical Assistance ("VITA"). VITA proposed to use two satellites to implement a store-and-forward message service in its provision of humanitarian assistance to individuals and groups in developing countries lacking an adequate telecommunications infrastructure. The VITA proposal represented a pioneering first step in the application of innovative low-Earth orbit satellite technology to meet basic survival needs of people in developing countries. Teledesic goes further, providing the capability for the advanced information services that increasingly are becoming essential to economic development and social welfare in the United States and throughout the world.

Open and ubiquitous, like a "Global Internet," the Teledesic Network will offer a means of providing a wide range of information services, from high-quality voice channels to broadband channels supporting videoconferencing, interactive multimedia, and real-time, two-way digital data. It will provide "bandwidth on demand," allowing users to adjust their channel capacity from one moment to the next to accommodate their various applications.

An innovative system design is required to provide these services. The only feasible frequency band internationally allocated to Fixed Satellite Service that meets Teledesic's requirements is the Ka band (30/20 GHz). Communications links operating at these frequencies are subject to high rain and terrain attenuation that can be mitigated by using a high elevation mask angle. To provide global access with fiberlike delays

requires a low-Earth orbit constellation. A high mask angle combined with a low-Earth orbit requires a large number of satellites to provide global coverage.

The Teledesic Network comprises a constellation of 840 satellites plus on-orbit active spares to achieve its quality and capacity objectives. The satellites are interlinked into a robust geodesic network topology. Each satellite contains a fast packet switch that routes packets to their destination along the path of least delay.

Using conservative assumptions regarding user distribution and usage levels, the initial Teledesic Network can realistically support the equivalent of 20 million users if the system were devoted solely to narrowband voice channels. In fact, the network capacity will be used for a smaller number of channels with a higher average bandwidth. The Teledesic Network has been designed to allow graceful growth to substantially higher capacities with future constellations. The Teledesic Network efficiently re-uses spectrum 350 times over the continental United States and 20,000 times globally.

The Teledesic Network will be fully interoperable with public networks in the United States and abroad. Teledesic will operate as a non-common carrier and will not market its services directly to users. Rather, it will provide an open platform for service providers in the United States and in host countries to bring affordable access to rural and remote locations.

Teledesic has developed and integrated into its proposed system a number of recent advances in telecommunications network architecture and satellite system design for which it will seek a pioneer's preference. These innovations include its autonomous network configuration, phased-array space antennas, an advanced onboard satellite orbit-determination and navigation system, an Earth-fixed cell coverage pattern, a fast-packet switch, an adaptive routing algorithm, and an advanced thermal control system. Some of these innovations build on prior research and development efforts in the United States defense programs and thus represent the first commercial application of these technologies. The Teledesic Network also utilizes technology which draws in part on work done in NASA's commercial satellite communications program, and has

undergone a design audit by NASA's Jet Propulsion Laboratory.

The unique and innovative attributes of the Teledesic Network demonstrate that a grant of Teledesic's application will serve the public interest and fulfill the FCC's statutory mandate under the Communications Act of 1934, as amended (the "Act"). The Act directs the FCC to make available to all of the people of the United States "a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges." The Teledesic Network fulfills this mandate. The Act further directs the Commission "to encourage the provision of new technologies and services to the public." The Teledesic Network also fulfills this mandate, and, in so doing, will serve our national interests by stimulating the growth of new and existing domestic industries, by reapplying space and defense-related technologies to new commercial applications, by providing badly needed jobs to highly trained and skilled workers in the space and defense industries, and by promoting important international goals, including the creation of global partnerships for the provision of advanced information services and improved access to health and educational opportunities throughout the world.

B. SYSTEM DESCRIPTION

1. Capabilities

The Teledesic Network uses a constellation of 840 operational interlinked low-Earth orbit satellites and up to four operational spares per orbital plane to provide global access to a broad range of voice, data and video communication capabilities. Through its global partnerships, the Network provides switched digital connections between users of the Network and, via gateways, to users on other networks. A variety of terminals accommodate "on-demand" channel rates from 16 Kbps up to 2.048 Mbps ("EI"), and for special applications up to 1.24416 Gbps ("OC-24"). This allows a flexible, efficient match between system resources and the requirements of users' diverse applications.

The Teledesic Network provides a quality of service comparable to today's

modern terrestrial communication systems, including fiber-like delays, bit error rates less than 10^{-9} and a link availability of 99.9% over most of the United States. The 16 Kbps basic channel rate supports low-delay voice coding that meets "network quality" standards.

The initial Teledesic constellation has a capacity equivalent to a peak load of more than 2,000,000 simultaneous full-duplex 16 Kbps connections, corresponding to over 20,000,000 users at typical "wireline" business usage levels. The actual user capacity will depend on the average channel rate and occupancy. The system design allows graceful evolution to constellations with much higher capacity without altering the system architecture, spectrum plan or user terminals. The Network capacity estimates assume a realistic, non-uniform distribution pattern of users over the Earth's land masses: some cells will generate over 100 times the traffic of the "average" cell.

The system provides 24 hour seamless coverage to over 95% of the Earth's surface and almost 100% of the Earth's population.

2. The Constellation Overview

The Teledesic constellation design supports the Network's requirements for quality, capacity and integrity. The only feasible frequency band internationally allocated to Fixed Satellite Service that meets Teledesic's spectrum requirements is the 30/20 GHz Ka band. High rain attenuation, terrain blocking, and other terrestrial systems in this band make it difficult for earth terminals to communicate reliably with a satellite at a low elevation angle. The Teledesic constellation uses a high elevation mask angle to mitigate these problems. A low orbit altitude supports fiber-like delays and reliable communication links that can operate at low power levels using small antennas. The combination of low altitude and high elevation mask angle results in a small coverage area per satellite and requires a large number of satellites for global coverage. A high degree of coverage redundancy and the use of on-orbit spares support the network reliability requirements.

The Teledesic constellation comprises 840 satellites plus on-orbit spares to meet

the Network's quality and capacity standards. The constellation is organized into 21 circular orbit planes that are staggered in altitude between 695 and 705 km. Each plane contains a minimum of 40 operational satellites plus up to four on-orbit spares spaced evenly around the orbit. The orbit planes are at a sun-synchronous inclination (approximately 98.2°), which keeps them at a constant angle relative to the sun. The ascending nodes of adjacent orbit planes are spaced at 9.5° around the Equator (See Figure D-1). Satellites in adjacent planes travel in the same direction except at the constellation "seams", where ascending and descending portions of the orbits overlap. There is no fixed phase relation between satellites in adjacent planes: the position of a satellite in one orbit is decoupled from those in other orbits. Figure D-2 illustrates the

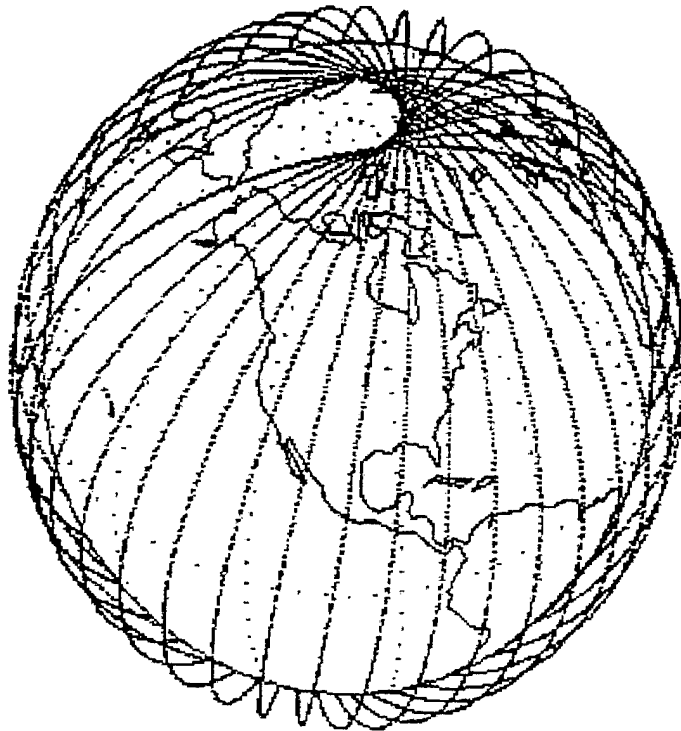


Figure D-1. Teledesic's Orbits - 840 satellites in 21 circular orbits between 695-705 km (Teledesic, 1994).

satellite coverage footprints over the continental U.S.

3. The Network

End users will be served by one or more local service providers in the United States and in each host country. Terminals at gateway and user sites communicate directly with Teledesic's satellite-based network and through gateway switches, to terminals on other networks. Figure D-3 is an overview of Teledesic's Network. The network uses fast packet switching technology based on the Asynchronous Transfer Mode ("ATM") technology now being used in Local Area Networks, Wide Area Networks, and the Broadband Integrated Services Digital Network ("B-ISDN"). All communication is treated identically within the network as streams of short fixed-length packets. Each packet contains a header that includes address and sequence information, an error-control section used to verify the integrity of the header, and a payload section

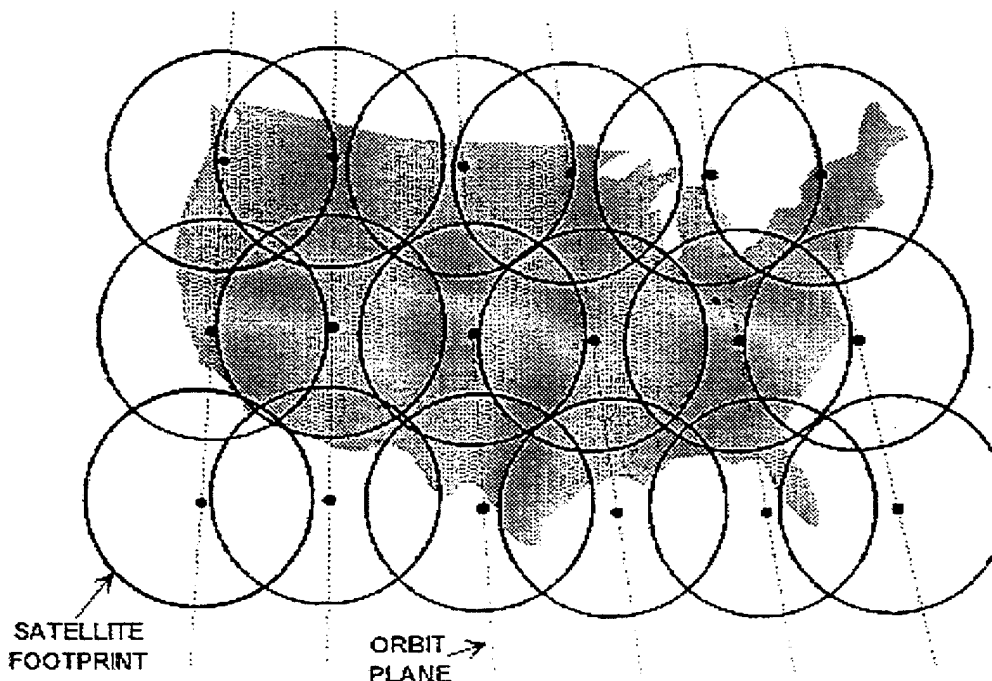


Figure D-2. Teledesics footprint coverage over the Continental U.S (Teledesic, 1994).

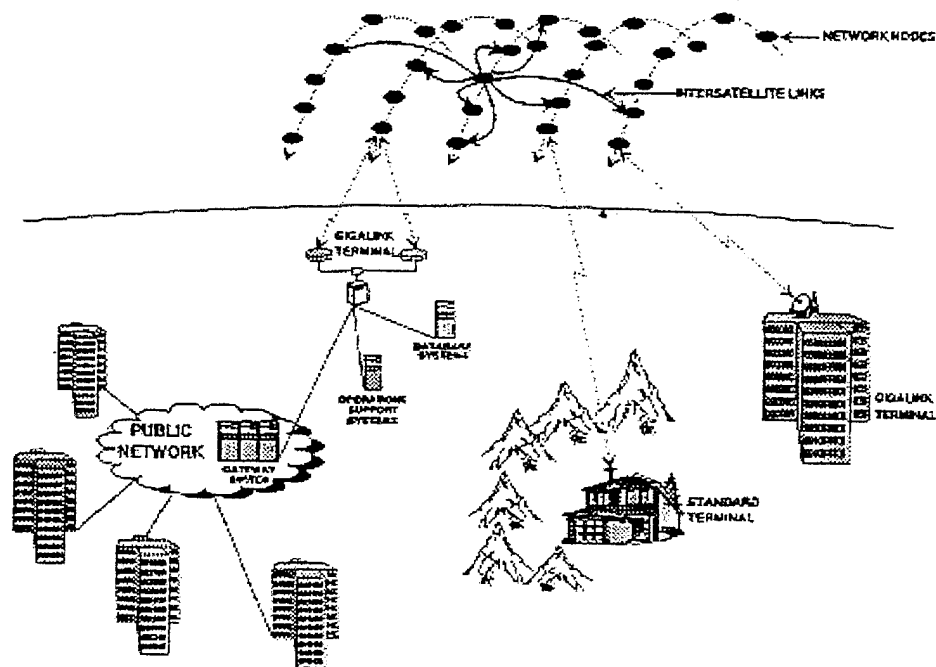


Figure D-3. The Teledesic network - Data communications via a geodesic dome covering the Earth (Teledesic, 1994).

that carries the digitally-encoded voice or data. Conversion to and from the packet format takes place in the terminals. The fast packet switch network combines the advantages of a circuit-switched network (low delay 'digital pipes'), and a packet-switched network (efficient handling of multi-rate and bursty data). Fast packet switching technology is ideally suited for the dynamic nature of a LEO network.

Each satellite in the constellation is a node in the fast packet switch network, and has intersatellite communication links with eight adjacent satellites. Each satellite is normally linked with four satellites within the same plane (two in front and two behind) and with one in each of the two adjacent planes on both sides. This interconnection arrangement forms a non-hierarchical "geodesic," or mesh, network and provides a robust network configuration that is tolerant to faults and local congestion.

4. Adaptive Routing

The topology of a LEO-based network is dynamic. Each satellite keeps the same position relative to other satellites in its orbital plane. Its position and propagation delay relative to earth terminals and to satellites in other planes change continuously and predictably. In addition to changes in network topology, as traffic flows through the network, queues of packets accumulate in the satellites, changing the waiting time before transmission to the next satellite. All of these factors affect the packet routing choice made by the fast packet switch in each satellite. These decisions are made continuously within each node using Teledesic's distributed adaptive routing algorithm. This algorithm uses information transmitted throughout the network by each satellite to "learn" the current status of the network in order to select the path of least delay to a packet's destination. The algorithm also controls the connection and disconnection of intersatellite links.

The network uses a "connectionless" protocol. Packets of the same connection may follow different paths through the network. Each node independently routes the packet along the path that currently offers the least expected delay to its destination (see Figure D-4). The required packets are buffered, and if necessary resequenced, at the destination terminal to eliminate the effect of timing variations. Teledesic has performed extensive and detailed simulation of the network and adaptive routing algorithm to verify that they meet Teledesic's network delay and delay variability requirements.

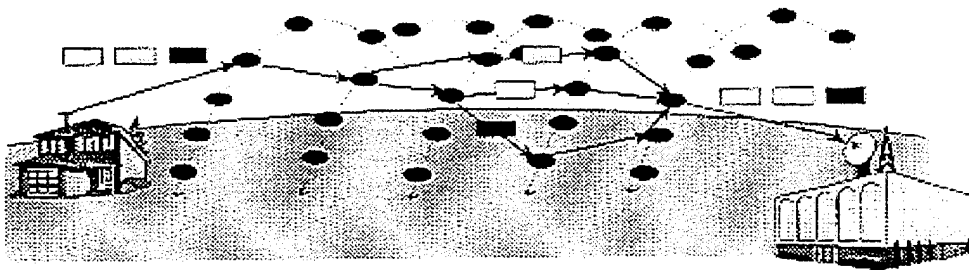


Figure D-4. Teledesic's Distributed Adaptive Routing Algorithm
(Teledesic, 1994).

5. Communications Links and Terminals

All of the Teledesic communications links transport data and voice as fixed-length (512 bit) packets. The basic unit of channel capacity is the "basic channel", which supports a 16 Kbps payload data rate and an associated 2 Kbps "D-channel" for signaling and control. Basic channels can be aggregated to support higher data rates. For example, eight basic channels can be aggregated to support the equivalent of an ISDN "2B + D" link (i.e., 128 Kbps payload and 16 Kbps D-channel). A Teledesic terminal can support multiple simultaneous network connections. In addition, the two directions of a network connection can operate at different rates.

The links are encrypted to guard against eavesdropping. Terminals perform the encryption/decryption and conversion to and from the packet format. The uplinks use dynamic power control of the RF transmitters so that the minimum amount of power is used to carry out the desired communication. Minimum transmitter power is used for clear sky conditions. The transmitter power is increased to compensate for rain.

The Teledesic Network accommodates a wide variety of terminals and data rates. Standard Terminals will include both fixed-site and transportable configurations that operate at multiples of the 16 Kbps basic channel payload rate up to 2.048 Mbps (the equivalent of 128 basic channels). These terminals can use antennas with diameters from 16 cm to 1.8 m as determined by the terminal's maximum transmit channel rate, climatic region, and availability requirements. Their average transmit power varies from less than 0.01 W to 4.7 W depending on antenna diameter, transmit channel rate, and climatic conditions. All data rates, up to the full 2.048 Mbps, can be supported with an average transmit power of 0.3 W by suitable choice of antenna size. Within its service area, each satellite can support a combination of terminals with a total throughput equivalent to over 100,000 simultaneous basic channels.

The Network also supports a smaller number of fixed-site "GigaLink Terminals" that operate at the OC-3 rate ("155.52 Mbps") and multiples of this rate up to OC-24 ("1.24416 Gbps"). Antennas for these terminals can range in size from 28 cm to 1.6 m as

determined by the terminal's maximum channel rate, climatic region and availability requirements. Transmit power will range from 1 W to 49 W depending on antenna diameter, data rate, and climatic conditions. Antenna site-diversity can be used to reduce the probability of rain outage in situations where this is a problem. GigaLink Terminals provide gateway connections to public networks and to Teledesic support and data base systems including Network Operations and Control Centers ("NOCCs") and Constellation Operations Control Centers ("COCCs"), as well as to privately owned networks and high-rate terminals. A satellite can support up to sixteen GigaLink terminals within its service area.

Intersatellite Links ("ISLs") interconnect a satellite with eight satellites in the same and adjacent planes. Each ISL operates at 155.52 Mbps, and multiples of this rate up to 1.24416 Gbps depending upon the instantaneous capacity requirement.

6. Earth-Fixed Cells

One benefit of a small satellite footprint is that each satellite can serve its entire coverage area with a number of high-gain scanning beams, each illuminating a single small cell at a time. Small cells allow efficient reuse of spectrum, high channel density, and low transmitter power. However, if this small cell pattern swept the Earth's surface at the velocity of the satellite (approximately 25,000 km per hour), a terminal would be served by the same cell for only a few seconds before a channel reassignment or "hand-off" to the next cell would be necessary. As in the case of terrestrial cellular systems, frequent hand-offs result in inefficient channel utilization, high processing costs, and lower system capacity. The Teledesic Network uses an Earth-fixed cell design to minimize the hand-off problem.

The Teledesic system maps the Earth's surface into a fixed grid of approximately 20,000 "supercells," each consisting of nine cells (see Figure D-5). Each supercell is a square 160 km on each side. Supercells are arranged in bands parallel to the Equator. There are approximately 250 supercells in the band at the Equator, and the number per band decreases with increasing latitude. Since the number of supercells per band is not

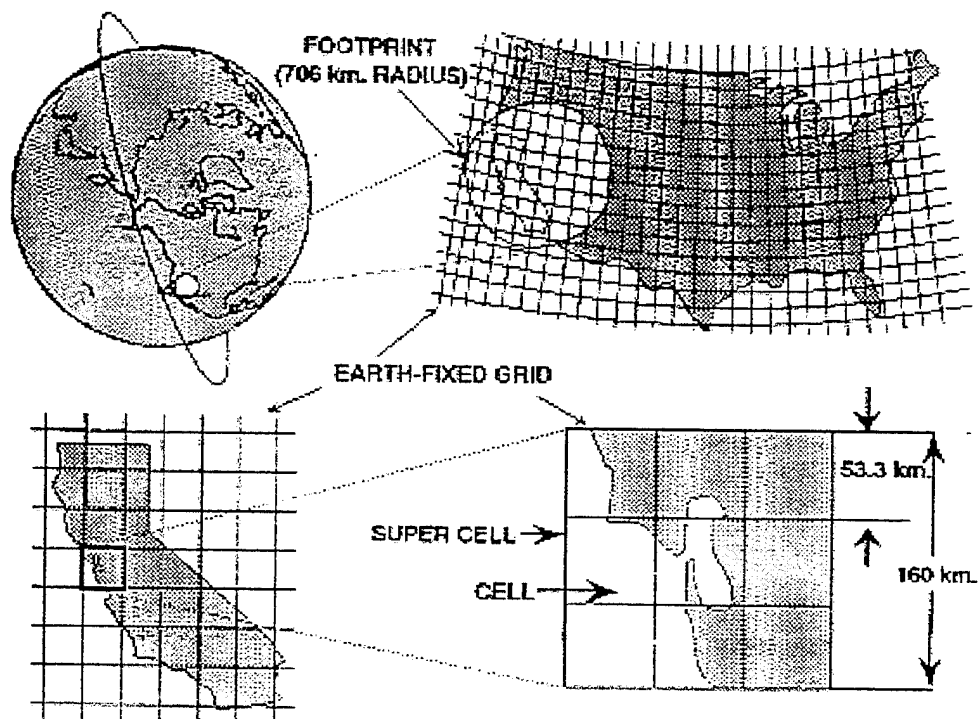


Figure D-5. Teledesic's Earth-fixed cells (Teledesic, 1994).

constant, the "north- south" supercell borders in adjacent bands are not aligned.

A satellite footprint encompasses a maximum of 64 supercells, or 576 cells. The actual number of cells for which a satellite is responsible varies by satellite with its orbital position and its distance from adjacent satellites. In general, the satellite closest to the center of a supercell has coverage responsibility. As a satellite passes over, it steers its antenna beams to the fixed cell locations within its footprint. This beam steering compensates for the satellite's motion as well as the Earth's rotation. (An analogy is the tread of a bulldozer that remains in contact with the same point while the bulldozer passes over. This concept is illustrated in Figure D-6.

Channel resources (frequencies and time slots) are associated with each cell and are managed by the current "serving" satellite. As long as a terminal remains within the

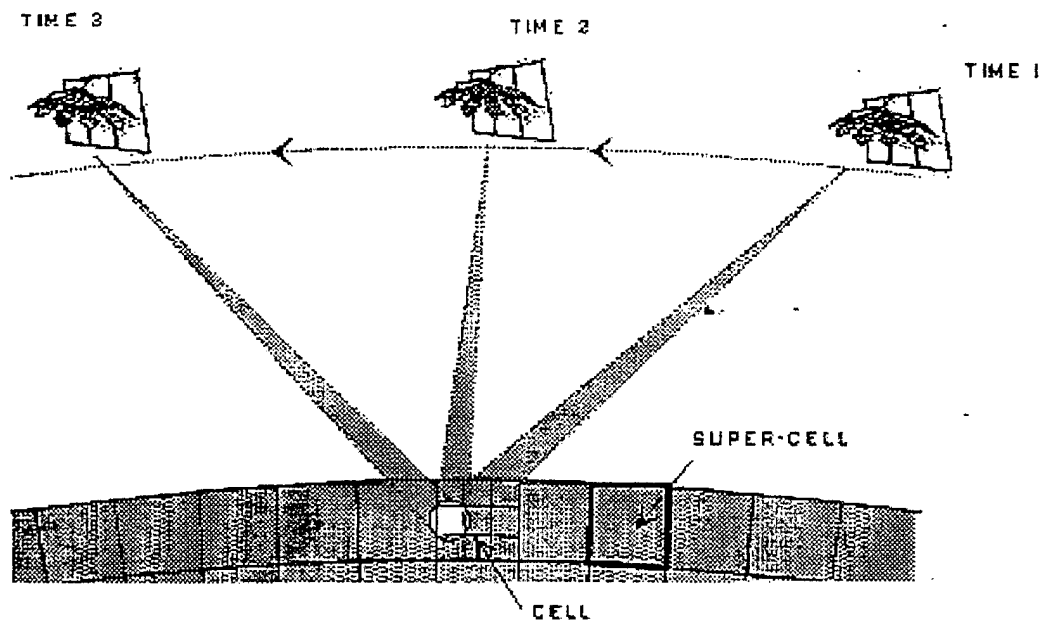


Figure D-6. Illustration of beam steering to an Earth-fixed cell (Teledesic, 1994).

same Earth-fixed cell, it maintains the same channel assignment for the duration of a call, regardless of how many satellites and beams are involved. Channel reassignments become the exception rather than the normal case, thus eliminating much of the frequency management and hand-off overhead.

A database contained in each satellite defines the type of service allowed within each Earth-fixed cell. Small fixed cells allow Teledesic to avoid interference to or from specific geographic areas and to contour service areas to national boundaries. This would be difficult to accomplish with large cells or cells that move with the satellite.

7. Multiple Access Method

The Teledesic Network uses a combination of multiple access methods to ensure efficient use of the spectrum (see Figure D-7). Each cell within a supercell is assigned to one of nine equal time slots. All communication takes place between the satellite and

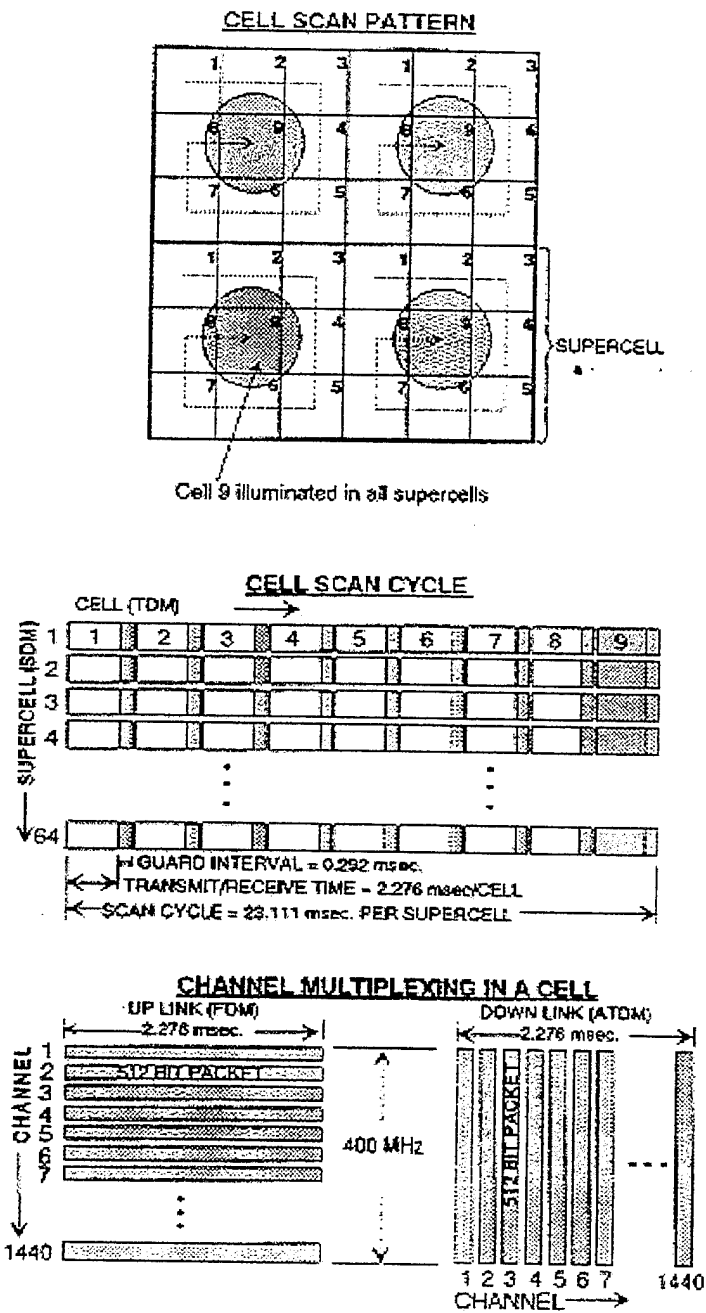


Figure D-7. Teledesic's Standard Terminal Multiple Access Method (Teledesic, 1994).

the terminals in that cell during its assigned time slot. Within each cell's time slot, the full frequency allocation is available to support communication channels. The cells are scanned in a regular cycle by the satellite's transmit and receive beams, resulting in time division multiple access among the cells in a supercell. Since propagation delay varies with path length, satellite transmissions are timed to ensure that cell N ($N = 1, 2, 3, \dots, 9$) of all supercells receive transmissions at the same time. Terminal transmissions to a satellite are also timed to ensure that transmissions from the same numbered cell in all supercells in its coverage area reach that satellite at the same time. Physical separation (space division multiple access) and a checkerboard pattern of left and right circular polarization eliminate interference between cells scanned at the same time in adjacent supercells. Guard time intervals eliminate overlap between signals received from time-consecutive cells.

Within each cell's time slot, terminals use frequency division multiple access on the uplink and asynchronous time division multiple access on the downlink. On the uplink, each active terminal is assigned one or more frequency slots for the call's duration and can send one packet per slot each scan period (23.111 msec). The number of slots assigned to a terminal determines its maximum available transmission rate. One slot corresponds to a Standard Terminal's 16 Kbps basic channel with its associated 2 Kbps signaling and control channel. A total of 1440 slots per cell scan interval are available for Standard Terminals.

The terminal downlink uses the packet's header rather than a fixed assignment of time slots to address terminals. During each cell's scan interval the satellite transmits a series of packets addressed to terminals within that cell. Packets are delimited by a unique bit pattern, and a terminal selects those addressed to it by examining each packet's address field. A Standard Terminal operating at 16 Kbps requires one packet per scan interval. The downlink capacity is 1440 packets per cell per scan interval. The satellite transmits only as long as it takes to send the packets queued for a cell.

The combination of Earth-fixed cells and multiple access methods results in very

efficient use of spectrum. The Teledesic system will reuse its requested spectrum over 350 times in the continental U.S. and 20,000 times across the Earth's surface.

8. System Control

The network control hierarchy is distributed among the network elements. Terminals and other network elements use a packet-based protocol for signaling and control messages (similar to the ISDN D-channel and CCITT Signaling System No. 7). The network handles these "control" packets in the same manner as normal information packets.

The highest levels of network control reside in distributed, ground-based systems that are connected via GigaLink Terminals to the satellite network. Database systems provide terminal/user feature and service profiles, authentication and encryption keys, call routing data, and other administrative data. Administrative systems, from "network-level" to local "incountry" systems, provide secure access to various levels of the database and billing systems.

High-level call control functions reside in feature processors and gateway switches. The feature processor controls intra-network calls as well as the initial setup of inter-network calls which involve a gateway. Only control and signaling packets are passed to the feature processor; user packets are transmitted through the network over the path of least delay. A gateway switch controls calls that are connected through that switch.

The satellite-based switch node includes some mid-level call control functions in addition to its packet routing function. It manages the assignment, supervision, and release of all channels in its coverage area and the "hand-off" of channels to other satellites. It also monitors channel signal quality and initiates uplink power control when required.

Terminals control some low-level call control functions similar to those of a cellular or ISDN functional signaling terminal. These functions include user authentication, location, registration, link encryption, monitoring and reporting of

channel quality, channel assignments and hand-offs, and D-channel signaling.

9. Satellite and Launch Overview

Teledesic's satellite bus is a lightweight, high-performance, high-power system based on modern components obtainable from existing aerospace suppliers. Components and subsystems are identical for all satellites and are designed specifically to take advantage of the economics of automated, high-volume production and test.

The on-orbit configuration of the Teledesic satellite resembles a flower with eight "petals" with a large boom-mounted square solar array. The deployed satellite is 12 meters in diameter and the solar array is 12 meters on each side. Each petal consists of three large electronically-steered phased-array antenna panels with integrated transmit, receive, and ancillary electronics. The scanning beam antenna arrays are located on panels that are oriented at angles to the Earth's surface that reduce the beam-steering requirements of each individual antenna to a few degrees. Coverage responsibility for all supercells within a satellite's coverage zone is divided among the individual scanning beam antennas based on the portion of the coverage zone within their scan limits. At any instant, each antenna is responsible for serving the cells of a single supercell that is within its scan limits. As the satellite movement causes a supercell to pass out of the view of one scanning beam and into the view of the next, coverage responsibility is passed from one antenna to the next. The fast packet switch routes packets addressed to a terminal within the satellite's coverage zone to the scanning beam antenna currently serving that terminal's cell. The antenna arrays on the inclined panels are elliptical in shape and produce elliptical patterns that compensate for the distortion from circular encountered at antenna grazing angles less than 90° with the Earth's surface.

The Teledesic satellite's baseplate also supports eight pairs of intersatellite link antennas, the two satellite bus structures that house the engineering subsystem components, and propulsion thrusters. A third satellite bus structure, containing power equipment and additional propulsion thrusters, is mounted at the end of the solar array boom. The solar array is articulated to point to the sun, and also acts as a solar shade to

enhance the performance of the payload electronics.

The satellite is stabilized in three axes and pitch-momentum biased. It is oriented to point at the nadir vector and is aligned with the velocity vector. Magnetic torquers and reaction wheels provide the required autonomous attitude control torques. Redundant low-thrust electric-powered thrusters provide the required orbit station keeping control.

Individual Teledesic satellites operate with a high degree of autonomy. The autonomous on-board orbit-determination and navigation systems track and maintain each satellite's position within the constellation. Each satellite monitors its status and periodically sends reports on its vital functions to the COCC. Exception conditions are reported immediately. The estimated on orbit lifetime of each satellite is 10 years. Degradables and consumables (i.e., solar array, batteries, propellant, etc.) have been sized to exceed the 10 year operational lifetime. Each satellite carries over twice the propellant needed to insert itself into its orbital position, to overcome atmospheric drag for its design lifetime (including one solar maximum), to reposition itself when required, and to perform a final deorbit maneuver.

The satellites are designed for stacked/piggyback launch on a variety of available medium and large launchers. The stowed satellite is roughly the size of a 4.2 meter diameter octagonal cylinder 1.3 meters high.

The initial constellation includes a number of active on-orbit spares that can be used to repair the Network immediately if a satellite is removed from service temporarily or permanently. Routine periodic launches will be used to maintain an appropriate level of spares in each orbit plane. Launch vehicles and satellites that have reached the end of their useful life are deorbited. They disintegrate harmlessly on re-entry, and will not create space debris. (Teledesic, 1994)

APPENDIX E. RADIO FREQUENCY BANDS

<u>Frequency Designation and Range</u>	<u>Letter Bands</u>	<u>Advantages</u>	<u>Disadvantages</u>
ELF/VLF/LF/MF 3 MHz and Below		<ul style="list-style-type: none"> -Long Range -Penetrates water and Vegetation -Groundwave Propagates Under Nuclear Blackout 	<ul style="list-style-type: none"> -High Power, Large Antennas -Bulky Equipment -Noisy equipment -Vulnerable to Intercept/DF -Low Data rates
HF 3-30 MHz		<ul style="list-style-type: none"> -Long Range -Modest Power and Cost -Mobile options -Optimum Path by Adaptive HF -Groundwave Propagates Under Nuclear Blackout 	<ul style="list-style-type: none"> -Skywave Vulnerable to Atmospheric Absorption, Blackout, and Intercept -Most Susceptible to Jamming unless Spread-Spectrum Modem Employed
VHF 300-300 MHz		<ul style="list-style-type: none"> -Low Power, Weight and Cost -Mobile and More channels -Less Susceptible to Intercept 	<ul style="list-style-type: none"> -Limited LOS Distances -Susceptible to Jamming -Crowded Spectrum
UHF 30-3000 MHz	L S	<ul style="list-style-type: none"> -Greater Bw and Channels -Small, Economical, Highly Mobile -mature technology -Satellite Application 	<ul style="list-style-type: none"> -Vulnerable to Nuclear Blackout -Less Susceptible to Jamming -Crowded Spectrum
SHF 30-300 Ghz	C X Ku	<ul style="list-style-type: none"> -Greater Bw and Channels -Routing Diversity -Widespread Connectivity -Satellite Application -Less Vulnerable to Nuclear Blackout/Scintillation 	<ul style="list-style-type: none"> -Limited frequency Allocation -Less Susceptible to Jamming -Satellite Ground Equipment is Large and Costly
EHF 30-300 Ghz	Ka	<ul style="list-style-type: none"> -Extensive Bw's -Jam resistant and LPI -Non-Crowded Spectrum -Small equipment -Satellite Application -More Channel Bw per Dollar -Least vulnerable to Nuclear Blackout/Scintillation Effects 	<ul style="list-style-type: none"> -Technology Risk -Susceptible to Rain and Atmospheric Attenuation -Expensive
Laser 30-300 Thz		<ul style="list-style-type: none"> -High Data Rates -Jam resistant and LPI -Amplifier Limited Bw -Potential Satellite Application 	<ul style="list-style-type: none"> -Attenuated by Atmosphere -Blocked by Vegetation -Capabilities not Exploited

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